THE

FOUNDRY TRADE JOURNAL

WITH WHICH IS INCORPORATED

THE IRON AND STEEL TRADES JOURNAL.

VOL. 31. Thursday, June 11, 1925. No. 460

PUBLISHED WEEKLY.

Subscription Terms: 15s. per annum.

Foreign and Colonial, 17s. 6d. per annum.

All Subscriptions are payable in advance.

All communications to be addressed to the Editor, or to the Publisher, as the case may be, of

THE FOUNDRY TRADE JOURNAL,
BESSEMER HOUSE, 5, DUKE STREET, ADELPHI,
LONDON, W.C.2.

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THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.

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Irish Foundry Conditions.

Dr. Moldenke, through the "Irish Builder and Engineer," has answered Mr. G. C. Castle's letter to that paper, which was also printed in THE FOUNDRY TRADE JOURNAL. As we suspected, both Dr. Moldenke and Mr. Castle were referring to the "Rein" system of desulphurising and refining cast iron. The Doctor, after clearing up this, says: "I am very much interested in the discussion now going on, and feel certain that good economic results will accrue to Ireland thereby. What seems to be needed, even before Government aid can direct the destiny of the foundry industry in Ireland, is that the foundrymen themselves get together to study their problems. But little can be done in the way of scientific betterment in the jobbing shops for the moment, and hence I had recommended a close study of the scrap problem as an economic necessity for Ireland. It is really in the speciality shop that greatest strides have been made so far in foundry practice on a scientific basis. Ireland needs such speciality shops, and might as well begin with the several lines used in the housing programme. There is also room for a beginning in making merchant steel of light shapes from scrap now exported. Later on, when the turn comes and the country rises in wealth and expands industrially—as it must to grow rich—the foundry industry will expand of necessity. Italy is a good example of this situation. But before this condition eventuates, there must come co-operation of the foundrymen, and close contact with the Government, so that the economic policies of the Free State may be shaped for a great future. This would seem to mean an Irish Foundrymen's Association. With the cordial relations now existing between the Foundrymen's Associations of America, Britain, France, Belgium, etc., a new Association for Ireland will be surely welcomed and all will strive to help the young brother get on his feet, benefit his country, and take his place in the ranks of the world foundry industry.

"Not only the Foundrymen's Association of Britain, but that of America, will be particularly helpful in this, I feel certain, for what is the good of one unit, in the advance of civilisation, is the good of all."

We do not agree with Dr. Moldenke that there is any need for an "Irish Foundrymen's Association." A reference to the conditions obtaining in Canada shows that that country's foundry technical needs are being met by membership of the American Foundrymen's Association. Thus in Ireland the conditions can be met by joining the Institute of British Foundrymen. If the Irish desired a domestic branch they would have a strong association at their backs to help them both financially and technically, until they were self-supporting. We are still convinced that no sound reason exists why Irish foundries should not join the British Cast Iron Research Association. In a published communication to Mr. H. Grattan, Dr. Moldenke is inclined to endorse our views as to the benefits to be accrued from membership of (English) British Foundry Associations. He says "Education is right. Plod along as best you can by way of metallurgical teaching, while the foundrymen have meetings for papers and study with visits to English and Scottish shops by way of attending the English foundrymen's meetings." We are sure by this that the Doctor is insisting on membership.

In this letter the Doctor rightly insists on the extreme importance of moulding machines to the Irish foundry industry. He deals with them by stating: "With the moulding machine I told you

about, and with a cheap and easy way of making match parts and match plates, many castings can be made of which there are only a few hundred wanted. So it might be a good idea to take up the possibilities of specialisation with the several foundries so that one gets a soil pipe machine, another a sanitary closet or possibly a stove machine, and so on, and thus specialisation is introduced, not by foundrymen asking for machines, but the machine builders deciding who shall get the classes of machines—at first, at least, until things get going. . . . In the meantime, whatever I can do at this end [United States of America] in the way of getting machines for you, if possible to pay for themselves—that is, on credit long enough to enable foundrymen to make the cost in profits—I will be glad to work for. The patterns could be made here [U.S.A.] and everything fitted, so that nothing more would be needed than to start the machine going." Unless the moulding machine referred to by Dr. Moldenke is one which has only just emerged from the development stage, it is almost certain to be known, if not well known, here. If it has no marketing arrangement in Great Britain, then there is a sufficiently large scope to warrant the creation of a service depôt manned by experts, where service of a higher—because of speed—value could be given to Irish foundries.

We believe a one-casting or even limited number of specialised castings foundry for this country, let alone Ireland, is too delicate a mechanism to attract the serious business man. It is always faced, under European conditions, with either shortage of work carrying standard overhead charges, or too much work and disappointed customers through late delivery. Again, for many specialities, such as railway castings, contracts are given out twice a year, and a few "misses" means temporary closing. European conditions demand several specialities, and when catering for one particular trade as many specialities as possible. This must not be read as meaning that no quantity production is generally possible, but it needs "tempering" to include the largest number of customers possible. Mr. Grattan has interpreted Dr. Moldenke's letter and applied them to actual local conditions, and rightly emphasises the value of co-operation between the various factors which are the basis of a successful foundry industry.

From this side of the Channel, we see the problem through a different pair of spectacles. We do not yet conceive the Irish Free State as a separate industrial entity—nor need it be. We agree that the long-distance movement of cast-iron scrap is metallurgically unsound. It should be re-melted on site and foundry business of importance can and should exist in Ireland. We suggest to Irish foundrymen that they have much to gain from the closest co-operation with their British confrères. There is for them more to be gained by an intensive study of British rather than American conditions.

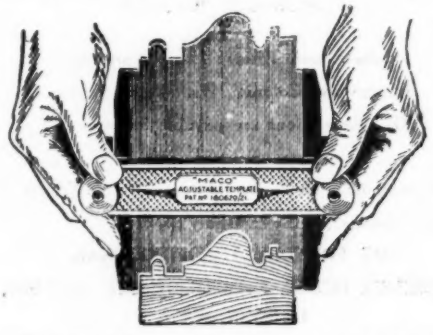
To put the Irish situation in a nutshell, we suggest the following steps should be taken: (1) They should form an Irish Branch of the Institute of British Foundrymen. (2) Appoint a consulting metallurgist to meet the college authorities with a view to rearranging the curriculum more adequately to serve the trade. (3) As a body approach the British Cast Iron Research Association, asking them to outline their work with special reference to Ireland. (4) Form a company for buying, grading and re-melting Irish scrap so as to provide themselves with varying grades of cast pig to analysis. Irish foundrymen will find, if they will endow themselves with a collective voice, that there are many possibilities in Ireland at present unrealised.

THE SKODA WORKS, which has a capital of 200,000,000 Czecho-Slovak crowns, had a net profit for the past financial year of 32,200,000 crowns, a decrease of 6,000,000 as compared with the preceding year. On the other hand, 102,000,000 had been transferred to debit reserves, as compared with 47,000,000 in the preceding year, while the other reserves had reached 82,000,000. A dividend was declared of 40 crowns, as compared with 32 crowns last year.

A Novel Template.

Shortly after publishing Mr. Markland's Paper on "The Making of Thin Section Patterns," we came across the "Maco" Adjustable Template and were impressed with its suitability for the strickling of plaster patterns in the way described in the article mentioned. We have not had a chance of trying out the template practically, but we do not anticipate there would be any difficulty in foundries borrowing one from the agents for trial.

The template which is substantially illustrated below consists in a line of hundreds of very fine



teeth of hard drawn solid brass, stated to be only 0.007 ins. thick. These laminations are held in position to two aluminium clamps, secured by two thumb screws and springs, by the tension of which the brass lamellae just take the shape of anything against which they are pressed, giving at the same time the male and female impression. A series ranging from 1¾ ins. to 1 ft. has been prepared. The marketing of the article, which is British throughout, is in the hands of Anderson and Company, Regent House, Kingsway, London, W.C.2.

Catalogues Received.

Cast-iron Pipes.—The monthly stock list for June, issued by the Staveley Coal & Iron Company, Limited, Chesterfield, is now available.

The London office of the Staveley Coal & Iron Company, Limited, is now Crown House, Aldwych, W.C.2.

Pulverised Fuel.—The International Combustion, Limited, of Africa House, Kingsway, London, W.C.2, have sent us a four-page leaflet describing the pulverised fuel plant which they have installed at the Municipal Power Station of the Birmingham City Corporation.

Temperature Regulation.—We have received from the Cambridge Instrument Company, Limited, of 45, Grosvenor Place, London, S.W.1, an advance copy of their List No. 150, describing Cambridge Automatic Temperature Regulators. The apparatus, which is described and illustrated, has important applications in the foundry. The automatic regulation of temperature, as distinct from its measurement, is being applied to a large and increasing number of metallurgical and industrial processes, ranging from the control of atmospheric conditions in a pattern shop to the automatic regulation of the temperature of a malleable iron annealing furnace.

Although the catalogue deals almost exclusively with the regulation of temperature, the regulators described can be applied with equal efficiency to the automatic control of humidity, pressure, and other physical conditions. No one form of measuring or control device is employed, but rather a combination of the most suitable methods of measuring the temperature to be controlled, with a means of control adapted to the particular requirements of the plant. For instance, in a gas-fired furnace or a plant operated by steam, air, oil or water, the device operates a valve either directly or through the intermediate of an electric relay. In electric furnaces it operates a relay which controls a circuit breaker in the main circuit. In other cases, the regulators can also be arranged to operate electric lights, gongs, klaxon horns, or other signals. We understand copies are available to our readers on application.

The Application of Metallography in Bronze Founding.*

By FRANCIS W. ROWE, B.Sc. (Research Dept., David Brown and Sons (Huddersfield), Ltd.).

Though the weight of castings in non-ferrous alloys produced yearly is only a small percentage of the total metal castings made, yet if the respective value of the castings in the different materials—non-ferrous alloys, cast iron and steel—is taken, it will be seen that a very large sum of money is involved and that a much greater capital outlay and a greater value per ton obtains when making non-ferrous castings.

If for this reason alone, it is necessary for the non-ferrous foundry to operate on even more economical lines than the iron and steel founder. Furthermore, owing to the present state of the engineering and allied industries as few parts as possible are made in brasses and bronzes, owing to their relatively high cost; and the weight of these are cut to the minimum. Thus it is essential that the castings should be as sound and strong as possible as the latitude in strength and the factors of safety are smaller than formerly. Consequently, all the results of metallurgical research and all the help that metallurgical instruments can give should be employed by the bronze founder to ensure that his castings shall be as sound and reliable as possible.

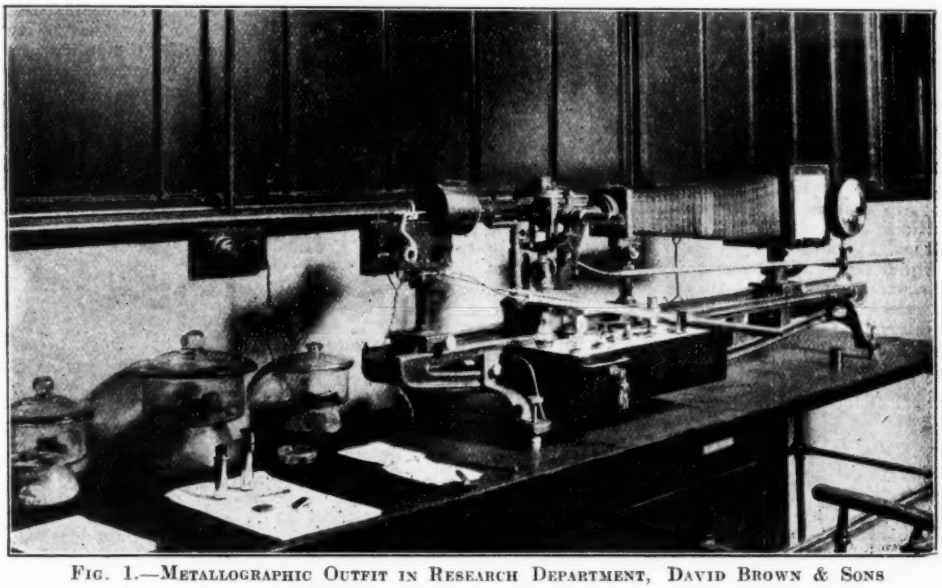


FIG. 1.—METALLOGRAPHIC OUTFIT IN RESEARCH DEPARTMENT, DAVID BROWN & SONS (HUDDERSFIELD), LIMITED.

In this respect the research work that has been done in universities and industrial laboratories throughout the world has proved of immense value to the bronze founding industry in helping to produce not only sounder castings, but castings of *regular* composition and strength and more fitted for particular duties in service.

Metallography embraces the study of the internal structure and constitution of metals and alloys. Since much of the internal structure of metals and alloys cannot be studied with the naked eye, the microscope must be largely used in examining their formation and constitution.

It is not the author's intention in this Paper to discuss the theory of the compound microscope, nor describe in detail the mode of preparation of metallographic specimens, as such information is available in most text-books. It should be mentioned, however, that as much useful information can be gained from a metallurgical microscopic outfit costing £20 or £30 as from the more expensive research outfits such as that in Fig. 1, which represents probably the latest and best achievement in microscopes for metallurgy. It is only when the desire or necessity arises for preserving records, in the shape of photographs of the various structures, that such an equipment is essential.

Metallurgical specimens for the microscope are polished on successive grades of fine emery paper and finally buffed on a revolving wet pad using a superfine abrasive such as aluminium or magnesium oxide. This removes the scratches left by the finest emery paper. Such a specimen is then examined under the microscope (before what is known as etching) to obtain an idea of the soundness or otherwise of the specimen. Porosity is thus easily discernible in specimens which to the naked eye in the polished state or in the fractured state appear perfect and is shown up more clearly than after the specimen is etched, as the colouration of the specimen may mask the holes. In brasses and bronzes most non-metallic inclusions such as sand, slag, etc., are easily seen in the unetched state, and the presence of lead in such alloys is indicated. Lead is practically insoluble in the ordinary alloys, and thus appears in the solid metal as patches (smaller or larger according to circumstances) of the pure metal. This being soft is usually picked out during the final polishing, and thus the metal appears to have small black pits over the specimen.

As porosity shows in a somewhat similar manner, it might be thought that confusion would occur as to which of the holes were due to lead and which to porosity, but actually this seldom occurs, as the lead appears in fairly regularly shaped patches, whilst porosity shows as jagged, uneven holes.

Figs. 2 and 3 illustrate this differentiation.

Revealing the Constituents.

After such examination the specimen is etched by immersing it in a chemical solution. The two most used etching reagents for brasses and bronzes are an acid solution of ferric chloride and ammonium persulphate solution.

The effect of the etching reagent is to corrode or colour the different crystals or constituents differently or unevenly. Thus after etching we are able to see the different constituents clearly. The different classes of constituents met with in non-ferrous alloys will be generalised separately.

(*a*) Solid solutions consist of crystals which are composed of variable proportions of one metal dissolved in another. Solid-solution crystals are not

* A Paper read before the Glasgow meeting of the Institute of British Foundrymen.

necessarily of definite composition, but may vary between the limits of solubility of the component alloys. Such crystals being true solutions, it is impossible to distinguish the two components under the microscope.

An alloy composed of two or more metals in such proportions that they dissolve completely in each other presents under the microscope in its normal state a similar appearance to that of a pure metal. That is, a number of crystals of the same structure throughout, only the grain or crystal boundaries showing.

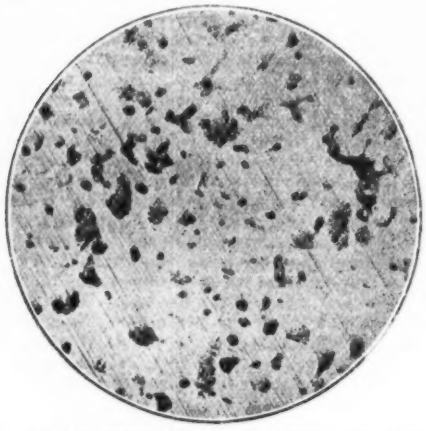


FIG. 2.—UNETCHED SPECIMEN—6 PER CENT. LEADED BRONZE × 200 DIAS.

Fig. 14A shows a photomicrograph at 200 diameters of a solid solution in which these characteristics are visible, whilst Fig. 5 shows one exactly similar except that the composition of the alloy is such that the different crystals appear of different colour due to the light being reflected from the crystals in a different manner. Many alloys in the cast condition, however, though solid solutions, show a different appearance from those in Figs. 14A and 5.

Fig. 6 shows a photomicrograph of an alloy of 80 per cent. copper and 20 per cent. nickel. The separate large grains are visible, but there is also an internal structure within the grains. This fir-tree or dendrite structure of what are known as

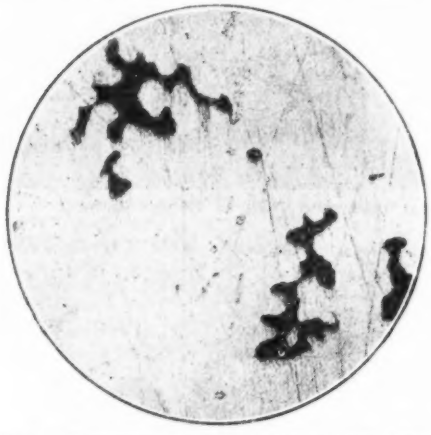


FIG. 3.—UNETCHED SPECIMEN—LEAD FREE BRONZE SHOWING POROSITY IN INTERSTICES OF DENDRITES × 200 DIAS.

"cored" crystals is common to many solid solutions in the cast condition, and is due to the method of solidification of the alloy. Solid solutions do not freeze at any definite temperature but over a range which may vary from 10 to 100 deg. C. In this instance the first solid portions to freeze out of the metal have been richer in nickel and the surrounding layers which have been built round the nuclei are progressively lower in nickel, and thus the difference in the rate of attack by the etching reagent. From the photomicrograph can be seen how the solidification has progressed in each grain. Thus an alloy is obtained consisting entirely of crystals of the same average composition but varying slightly in themselves. Such coring effects may be removed by annealing the alloy, although it must be pointed out that with some classes this internal coring is extremely

FIG. 5.—SOLID SOLUTION × 100 DIAS. GRAIN BOUNDARIES AND DIFFERENTLY ORIENTATED CRYSTALS.

difficult to remove—notably in the alloys of which the photomicrograph is taken—the copper-nickel group.

Eutectics and Eutectoids.

(*b*) Eutectic signifies alloy with the lowest melting point. The eutectic of any alloy of two or more metals is that definite composition which solidifies at the lowest temperature. The solidi-

FIG. 6.—SOLID SOLUTION × 50 DIAS. CORING EFFECT AND DENDRITES.

fication of a eutectic takes place at one definite temperature, and not as with solid solutions over a range of temperature.

FIG. 7.—PHOSPHOR COPPER (9 PER CENT. P) × 50 DIAS.

Eutectics, consisting as they do of two constituents intimately mixed together, always pre-

sent a duplex structure, though in many instances the higher powers of the microscope are necessary to show this feature. The "pattern" of the duplex structure of a eutectic varies with different alloys and different methods of cooling, but they can usually be easily identified as they possess similar general characteristics.

Fig. 7 shows a photomicrograph of an alloy containing 9.0 phosphorus and 91.0 per cent. copper. The major portion consists of the eutectic of copper and copper phosphide with one dendritic crystal of copper phosphide. The alloy contains slightly more phosphorus than is required for the

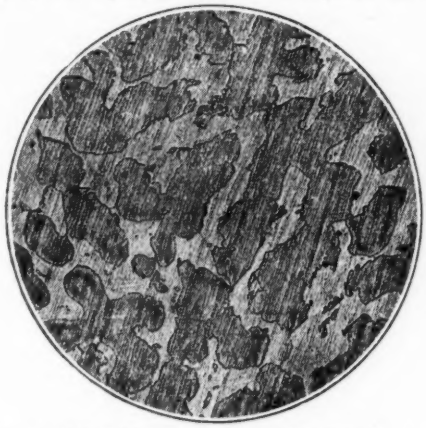


FIG. 8.—TIN BRONZE QUENCHED 650 DEG. C. × 400 DIAS.

formation of all eutectic (8.2 per cent.), and thus some copper phosphide remains free. It will be noticed that the eutectic is coarser in some parts than in others, that is at the edges of the grain, though the grain boundaries are not usually distinguishable except by this feature.

Eutectoids, as their name implies, are similar to eutectics. The essential difference is that whilst eutectics are formed by the simultaneous freezing from the liquid state of two constituents of an alloy in definite proportions, eutectoids are formed by the decomposition in the solid at a definite temperature of a solid solution.

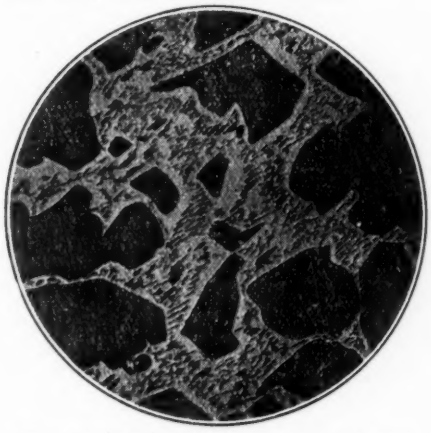


FIG. 9.—TIN BRONZE AS CAST × 400 DIAS.

The formation of a eutectoid may be perhaps best illustrated by a specific example. An alloy of 80 per cent. copper, 20 per cent. tin commences to solidify about 880 deg. C. At 790 deg. C. the alloy is quite solid and consists of a mixture of two solid solutions known as the alpha and the beta. This structure continues until the temperature reaches 525 deg. C. Fig. 8 shows the structure of such an alloy in this range being obtained by quenching a sample at 700 deg. C. and thus retaining the structure at that temperature.

At 525 deg. C. the beta solid-solution breaks up into a eutectoid composed of alpha solid-solution and delta solid-solution as its constituents. The appearance of the alloy in this condition is shown in Fig. 9. Fig. 10 shows the eutectoid at a higher magnification when the two constituents are seen more clearly.

Intermetallic Compounds.

(*c*) *Intermetallic compounds* are compounds of two or more metals of *definite* chemical composition. They combine with the other portions of an alloy similarly to a pure metal or a solid solution, and may form solid solutions or eutectics with other solid solutions or the pure metals. Certain classes of metallic compounds are easily identified by the fact that they solidify at one definite temperature and not over a range, and also the fact that they show no coring effect in the cast condition like many solid solutions.

Perhaps one of the commonest intermetallic compounds of this definite class that is met with

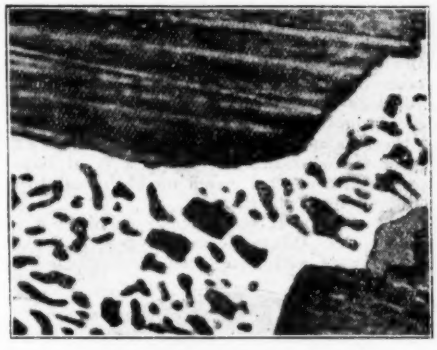


FIG. 10.—ALPHA-DELTA EUTECTOID IN TIN BRONZE × 2,000 DIAS.

in ordinary bronze founding practice is the compound copper phosphide Cu_3P.

The photomicrograph Fig. 7 shows this compound—a dendrite or crystal of the compound and the mixture of the compound with practically fine copper as a eutectic. Fig. 11 shows an alloy containing 4.5 per cent. tin; 1.5 per cent. phosphorus, and 94 per cent. copper. The structure consists of a ground mass of solid solution (alpha) of tin in copper, whilst the nodules are phosphide of copper Cu_3P.

General Characteristics of the Different Constituents.

It is difficult to generalise on the physical properties of various types of constituents, as exceptions are fairly frequent. Generally speaking, however, solid solutions are comparatively soft and ductile and capable of being worked cold. They are similar in this respect to the majority of pure metals. Eutectics are hard—generally much harder than their constituent metals—and are usually very brittle and find very little commercial application as castings, though here again exceptions must be made as one of the most

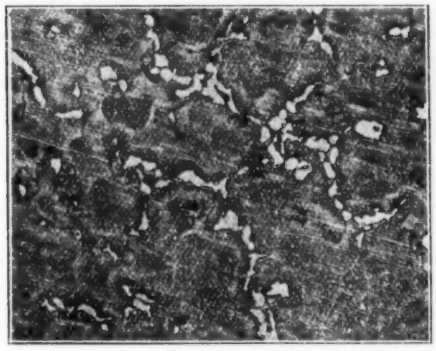


FIG. 11.—FREE COPPER PHOSPHIDE NODULES IN LOW-TIN PHOSPHOR BRONZE × 100 DIAS.

promising of the aluminium casting alloys—Alpax—is the eutectic alloy of aluminium and silicon.

Eutectoids are generally much harder than solid solutions but not so hard nor so brittle as eutectics and many commercial alloys—notably the bronzes and gunmetals—contain an appreciable and important proportion of a eutectoid.

Intermetallic compounds in their pure state are harder and even more brittle than eutectics,

particularly those which show the characteristics of an intermetallic compound in a marked manner.

Examination of Raw Materials.

It must be confessed that, chiefly owing to the perfection of manufacturing conditions, the scope of the microscope in the examination of virgin metals is limited. Metals such as electrolytic copper, tin, lead and spelter and nickel usually come into the market in such a high state of purity that their performance for casting purposes may be relied upon and very little save analytical control is needed, and that only occasionally if standard brands are purchased. Perhaps the one exception is ingot copper.

"Best Selected" ingot copper always contains an appreciable and important amount of oxygen. Copper which is free from oxygen will not cast soundly into ingots, and therefore, in the refining processes for copper, some oxygen is left in to ensure clean-looking ingots which will break with a nice fibrous fracture.

As there is no type of non-ferrous alloy which is better for containing oxygen, it is of importance to keep a careful watch on the possibility of introducing this constituent.

A good quality of B.S. copper should not contain more than 0.1 per cent. oxygen, and excess of this amount will result in poor castings being obtained with many alloys. The estimation chemically of oxygen in copper is a lengthy and intricate process, but the detection and rough approximation under the microscope is simple. Oxygen in copper appears as cuprous oxide as a eutectic with copper, and very small amounts are easily discernible.

Needless to say, electrolytic copper does not suffer from this impurity and is worth the extra cost for certain classes of alloys.

Fig. 14.—Admiralty Gunmetal, as Cast × 200 dias.

Alloys of the Bronze Class.

The basis of all alloys of the bronze class is the system copper-tin. The alloys which find use in engineering practice contain up to 16 per cent. tin and varying amounts of zinc, lead or phosphorus.

Pure copper-tin alloys—that is, those made without any deoxidant or addition of other metal—are seldom used nowadays. Copper-tin alloys are among those which are very susceptible to the presence of oxide. Oxide in these alloys renders them extremely sluggish when molten and liable to casting defects and serious weakness in strength due to lack of cohesion in the crystals. The oxide in these alloys is tin oxide—one which it is extremely hard to remove from the metal when once formed.

Consequently, the general practice is to prevent the formation of oxide by adding either zinc or phosphorus to the metal at the right time—*i.e.*, before alloying the tin

Copper-tin alloys form an extremely interesting and important study from a metallographic point of view. Theoretically copper is able to dissolve 12 to 13 per cent. of tin. That is, alloys of copper with 12 to 13 per cent. tin should form a homogeneous solid solution. In actual practice this does not occur, as the comparatively rapid rate of cooling prevents the alloy from attaining what is known as its stable state, and very prolonged annealing is required before the alloys attain this final state. Actually, in ordinary bronze-founding practice, the limit of solubility is between 6 and 7 per cent., depending on the casting and cooling conditions. That is, an alloy of 95 copper and 5 per cent. tin will consist when solid of homogeneous solid solution (save for a slight coring effect) known as alpha, and will show nothing but grain boundaries under the microscope. Such an alloy, with care, can be rolled and drawn.

Above 7 per cent. tin it will be seen that a new constituent has made its appearance. This is the alpha-delta eutectoid whose constitution and formation was discussed in the paragraph on eutectoids. It is to this alpha-delta eutectoid that the bronzes owe their wearing properties. It is considerably harder than the beta solid solution from which it is formed, and great care must be taken to see that it is formed where the best qualities of the bronze are required. The author has known many failures and shortcomings in bronzes due to insufficient appreciation of the functions of this important constituent.

As has been pointed out previously, if a bronze is quenched in water from a temperature of 550 deg. C. or above, the beta solid solution is retained and no eutectoid is present. Bronzes in this condition are stronger, very much tougher, and more ductile than in their normal condition, but they are not suitable for withstanding wear. Any alloy to withstand wear and at the same time give a low co-efficient of friction must consist of hard particles embodied in a soft matrix, and there must be a considerable difference in hardness between the two constituents. In a bronze alloy there is very little difference in hardness as measured by the Brinell method between a normal and a quenched sample, but there is a great difference in their capacity to resist wear, because in the quenched alloy the difference in hardness between the two constituents has been levelled up, the soft matrix has been hardened, and the hard eutectoid particles have been transformed into the softer beta.

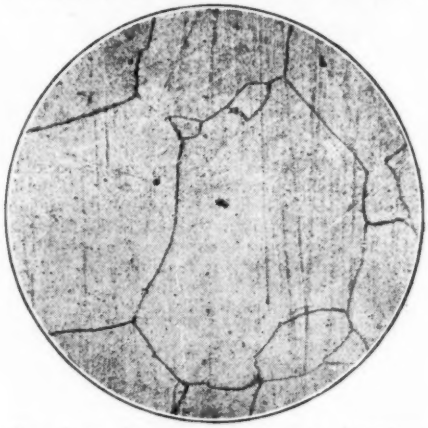


Fig. 14a.—Admiralty Gunmetal Annealed × 200 dias.

The practice of quenching bronze or gunmetal castings to secure tougher and stronger metal is one which should not be indulged in without the fullest knowledge of the duties imposed on the casting in service. Similar harmful effects may result for the same reasons from the practice of baring the heavy portions of bronze castings immediately they are set and throwing water over them to prevent liquation or bleeding, and in addition the liability to set up severe strains which may result in early failure in service.

Somewhat similar conditions appertain with the question of annealing—heating the castings up to 600 or 700 deg. C. and allowing them to cool slowly. Where the castings have to withstand wear this again is very harmful. Nature has providentially arranged that the rate of cooling which ordinarily obtains in sand castings is the one which gives in bronzes and gunmetals a good structure to resist wear.

(To be continued.)

The Present Status of the Laboratory Investigation of Sands.*

yH. RIES, Ph.D.†

The laboratory investigation of moulding sands is not a new idea, for tests of one sort or another have been tried for a number of years, the fineness test being perhaps the one most commonly applied. Many of these tests have been made, however, according to the individual ideas of the experimenter, so that they conformed to no common standard, and we consequently lacked a common basis for comparison, which is, of course, very unfortunate.

In recent years there has been a strong movement not only in the United States, but also in Europe, looking both towards a refinement of laboratory test methods, as well as their standardisation. The advantage of this is almost self-evident, but the reasons may be stated here.

Standard tests (1) enable the consumer to determine the qualities of new sands, and intelligently compare them with others already in use; (2) permit the producer to keep a check on the uniformity of his product; (3) make it possible for the consumer to check all shipments as received in order to determine whether they conform to his requirements and specifications; and (4) are of value for daily control in the foundry. The last of these advantages is by no means the least, and its rapid spread in the United States, accompanied by reports of those who are using it, testify to its importance and value.

Whilst the different tests, which will, it is hoped, eventually become standardised, may be large in number, it is not to be thought that all of them will be used for foundry control. Indeed, the number employed for the latter purpose will probably be limited, but additional ones may serve for the examination of new sands submitted to the consumer by the producer, and still others may be used mainly in research work on sands.

The important point, however, as is generally realised, is the necessity of getting the various methods standardised. In addition they should be as simple as possible, and those which are to be used daily in the foundry should not only be easily understood, but the apparatus employed should be as nearly foolproof as possible, and of a durable nature.

In the present contribution, the writer intends to deal chiefly with what has been done in the United States, but this is not to be taken as an indication that American eyes have been closed to the work of their fellow investigators across the sea. Indeed, they have followed these efforts in the same lines with the keenest interest and appreciation. Some references to and comparisons with foreign tests will be made.

Joint Committee on Moulding Sand Research.

In December, 1921, there was organised a Joint Committee on Moulding Sand Research, acting under the auspices of the American Foundrymen's Association and the Engineering Division of the National Research Council. This committee included not only representatives of the foundry industry, but also one from each of the several technical societies or other scientific organisations which might be interested in such an investigation.

An executive committee was selected to exercise control over the entire investigation, except the handling of the funds required. The latter are kept and disbursed by the treasurer of the American Foundrymen's Association, which is the financial and chief technical sponsor of the joint research.

As the work of the investigation was somewhat diversified, it was recognised at once that sub-committees would be required to take charge of and carry on the several phases of the work. As a result there were organised sub-committees on (1) conservation and reclamation; (2) geological surveys; (3) tests; (4) finance; and (5) publicity. Sub-committee number four was particularly important, as such a broad investigation could not be carried on without funds. It is a pleasure to remark that contributions to the fund for research have been appreciable.

To refer more specifically to the work of the Sub-Committee on Tests, it may be said that the development of standard tests by this committee had a two-fold importance, because they were not only to be used by the foundrymen themselves in their own laboratories, but were also to be used at the testing stations supported by the American Foundrymen's Association, where the sand samples collected by the different state geological surveys—to date over 800 samples from 15 states—are being investigated.

A point not to be overlooked is that each testing method recommended by the sub-committee on tests is tentatively adapted for one year's trial, in order to determine by use whether it meets all demands, needs revision, or should be replaced by a better test discovered during its probation period.

The recommendations thus far made by the Sub-Committee on Tests have been printed in a pamphlet which was issued by the American Foundrymen's Association in June, 1924.

Fineness Test.

This test, as at present recommended by the American Foundrymen's Association, is essentially a sieve test. For core sands with no clay the sand is sieved dry, but for those sands containing clay substance the sand is first shaken in water to which NaOH has been added, and the so-called clay substance separated from the "grain" by siphoning. For the fineness test sieves Nos. 6, 12, 20, 40, 70, 100, 140, 200 and 270‖ are used. That material which passes 270 is caught in the pan. The openings of the No. 270 are 0.053 mm. and the average diameter of the material remaining in the pan is about 0.035 mm.

For purposes of comparison, it is naturally imperative that the same sieve sizes should in all cases be used, although even now in the U.S. this is not always done. It is, furthermore, important that the sieves should be calibrated before use, because even carefully woven ones may show variation in the openings for a given size. The diameter of the sieve openings, the diameter of the wires, and the allowable deviation or tolerance of each from the specified dimensions have been published by the U.S. Bureau of Standards.†

That the test works satisfactorily has been shown beyond doubt, and there is no difficulty in obtaining duplicate results which check quite closely if the sand is of uniform character. Some criticism has, however, been made of the so-called clay substance, which may include both colloidal clay and fine silt, and the point has been raised by some, whether for purposes of scientific investigation it might not be well to separate these two constituents. Whether it is essential for general foundry work is open to discussion.

Another point to be considered perhaps, is the effect of tap water on the process. Water from this source may contain electrolytes, and may vary in its composition from place to place. The question then arises, should the sand be tested with distilled water. From the foundryman's viewpoint this may be regarded as decidedly inconvenient, and moreover insufficient data are as yet available to decide whether it is necessary.

The method of determining the texture of the sand is different from that advocated by many foreign investigators and writers, such as Professor Boswell and others,‡ who commonly use

* This Paper was submitted on behalf of the American Foundrymen's Association to the Glasgow Conference of the I.B.F.

† Dr. Ries is Chairman of the Sub-Committee on Tests, Joint Committee on Moulding Sand Research.

‖ These numbers refer to the U.S. Bureau of Standards sieve series.

† Revised specifications giving slightly greater tolerance limits were issued by the U.S. Bureau of Standards in April, 1924.

‡ *See* P. G. H. Boswell, "A Memoir on British Resources of Refractory Sands for Furnace and Foundry Purposes," Part 1, 1918.

the elutriation process, and, the author believes, regard it as better because, as they state, it separates the finer sizes. They, moreover, criticise the sieve test, because they claim it does not perform accurate sorting, since large elongated grains might go through the meshes endwise, and hence be caught on the finer sieves to be weighed with the fine particles, in whose company they should not be found.

In this connection attention is drawn to the following facts: (1) Elongated grains are, it is thought, the exception rather than the rule in most sands; (2) the elutriation method requires considerably more time than the A.F.A. sieve test; (3) the elutriation method requires the use of sieves for the medium and coarser sizes, but the larger sizes separated by water, come within the range of the finer sieve sizes of the A.F.A. test; (4) the A.F.A. method is in actual practical use in foundries in the United States, and is giving satisfactory results; (5) the A.F.A. sieve test separates particles down to 0.035 mm. dia.; and (6) although the author has seen the results of many elutriation tests plotted, he does not remember having seen any practical use made of this extreme separation of the smaller particles.

Expression of Results of Fineness Test.

Having separated the sand into its different groups of grain sizes, next must be considered the best manner of expressing the results of the

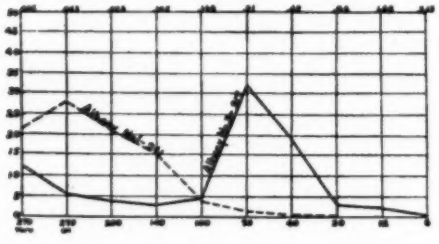


Fig. 1.—Sieve Meshes Plotted without Regard to Size of the Opening.

tests. Obviously, to record them in tables is the most convenient way, but where a large number of sands are so arranged, a comparison of them is not always a rapid operation.

This leads then to the possibility of expressing the texture graphically, as by curves, or by means of a number.

Fineness Graphs.

If curves are used to represent the texture one is obliged to choose between several methods any

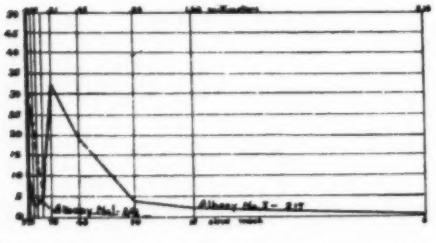


Fig. 2.—Sieve Openings are Correctly Spaced on Rectangular Co-ordinates.

one of which may at least be considered fairly satisfactory. These are (1) the use of rectangular co-ordinate paper (Fig. 1), plotting the percentage of each sieve as ordinates, against the sieve sizes ranged as abscissæ. On such paper, the sieve sizes may be plotted at regular intervals, and the abscissæ representing them may be correctly spaced in proportion to the real size of the screen openings (Fig. 2). The first method is used by many, the second by few, and it is open to the objection that the coarser sizes take up all the room on the chart, crowding the smaller ones together at one end.

(2) The use of logarithmic co-ordinates for the screen sizes while retaining the rectangular co-ordinates for vertical plotting of percentage retained by each sieve (Fig. 3). If logarithmic co-ordinates are used it seems best to plot the size of the actual sieve openings. Two types of curves appear to have been used, regardless of the kind of co-ordinates employed. One of these is the cumulative curve (Fig. 4), probably more used in Europe than America. The other gives the actual percentage retained on each sieve. It may be a matter of personal choice which one is used, but, to the writer, the latter of the two

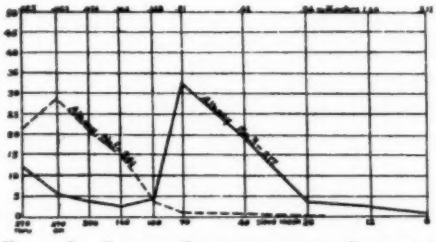


Fig. 3.—Sieve Openings are Correctly Spaced on Logarithmic Co-ordinates.

seems preferable, because any excess of certain sizes is detected at a glance, although it may be argued that the cumulative curve would also show it by a pronounced local steepening of the line.

Fineness Figure.

The second method of expressing the fineness is by means of a figure, which may be called the *average fineness figure*. This can be done in several ways. One, sometimes referred to as the Scranton method, consists in multiplying the weight of sand retained on each sieve by the mesh of the next coarser sieve. The sum of these products is divided by 100 and called the average fineness. The objection to this is that sands which differ markedly in their texture may give

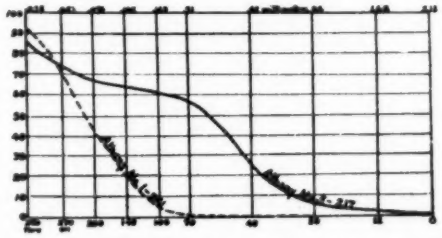


Fig. 4.—Cumulative Percentages with Sieve Openings on Logarithmic Co-ordinates.

almost identical fineness figures, as the following examples (Table I) taken from a forthcoming Paper by Mr. C. M. Nevin will show:—

Table I.—*Illustrating that similar fineness figures are given by totally different sands.*

Mesh.	No. 1.	No. 2.	No. 3.
6	0.0	0.10	1.10
12	0.0	1.00	5.03
20	0.02	9.70	9.70
40	0.72	5.76	8.70
70	19.68	19.60	10.60
100	20.18	11.30	11.30
140	14.50	10.56	10.56
200	8.26	9.22	9.22
270	9.46	13.50	13.50
270 (Pan) ..	11.40	11.00	12.01
Clay substance ..	16.70	9.14	9.14
Aver. fineness ..	98	98	98

Better results are apparently obtained if the percentage retained on each sieve are divided by the mesh size of that sieve, and the sum of these taken, and yet this second method is not without its objections. The first one works best with coarse sands and the second with finer grained ones.

One may, moreover, question whether such an average fineness figure really shows as much as a curve, from which the percentage and distribution of the different sized grains can be read at a glance.

Use of Fineness Test.

Most foundrymen, it is thought, recognise the value of a fineness test. The texture of the sand serves to indicate the venting qualities of the material, as well as the smoothness of surface finish which it might produce, unaided by any facing material, as well as the approximate size of casting that can be poured in it. It is extremely useful as one of the tests to be applied in checking up new consignments of sand.

Grading Sands.

In a recent Paper before the American Foundrymen's Association, Mr. C. M. Nevin has presented some very suggestive ideas on the grading of sands by means of the fineness tests. His views worked out in connection with a study of some 60 samples of Albany sand. Plotting all those of the same producers grade on co-ordinate paper, it was found that they agreed quite closely. This permitted drawing what might be called an *average curve*. If now on either side of this two other curves are drawn which include most of the variations from the average line, shown by the sands of that grade, and shade the area between these two lines, it gives what Nevin suggests calling an *area curve*. (Fig. 5, representing the area curve of No. 3, Albany.) Such area curves were constructed for the different grades of Albany sand. Having then the curve plotted, any new sand from that district can be fitted into its grade. This, of course, refers to texture, and not to any other properties, although permeability is within certain limits more or less associated with texture.

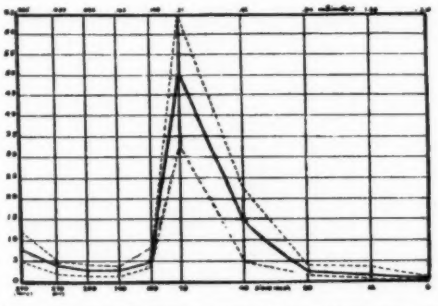


FIG. 5.—BY SHADING THE AREA ENCLOSED BY THE DOTTED LINES AN "AREA CURVE" FOR GRADING SANDS. ACTUALLY IT IS NO. 2 ALBANY.

Now to apply the grading theory a little further, let it be supposed that some producer in another territory is selling a sand which he designates as No. 6 or 3 F., and yet whose fineness curve fits nicely in the area curve of a No. 1 Albany. Why should this not be called a No. 1 sand also? In other words, one might probably reduce these descriptions to common terms, or the same language. The idea seems attractive to many, and a sub-committee of the A.F.A. has been recently appointed to develop it, if possible. If practicable, it is a step towards the development of sand specifications, which may be given out by the consumer to help the producer to supply him with what he wants.

Vibratory Tests for Fineness.

Every industry has its short-cut methods for making certain tests, and the foundry industry is no exception. Indeed, as many know, a description of some was recently presented before the French Foundrymen's Congress.* In the United States some attention has been attracted to what is known as the Smith Vibratory Test, and as some rather strong claims have been made for this method, it may not be out of place to devote a few words to it.

Briefly stated, a mass of sand and water are shaken thoroughly by hand in a test tube or bottle about 6 in. high and 1 in. diameter. The suspension is then placed on a vibrator for half an hour, whereupon the grains of different sizes settle to the bottom of the tube, the coarsest on the bottom and the finest on the top, presenting a beautiful series of layers. The thickness of these is measured by means of a scale, thus obtaining the percentage of the several grades. The layer of finest material is classed as bond. Mr. Smith has sought to show that this one simple test may take the place of all the standard ones used in foundry control, but this does not appear to be the case, as the following comparisons taken from a Paper by Dietert on foundry control will show.

"Nearly all sand showed a larger amount of clay substance. A part of the bond measured in the vibratory test is pan material. The percentage of bond as shown by vibratory test does not enable one to estimate the permeability or strength of the sand. The standard permeability and strength tests can be made much quicker than the vibratory test." Where the same sand mixture is being used from day to day, the vibratory test will give an approximate idea of whether it is running uniform or not.

Fineness and Permeability.

Observations thus far made indicate, of course, that a general relation exists between texture and permeability, but it is only a very general one. If we could calculate the permeability from the fineness, it would be very convenient. Thus far no one has suggested a satisfactory method, and it seems doubtful whether it can be done.

Bonding Strength.

This all must admit is a very important property of moulding sands, and consequently one for which there should be a satisfactory means of measurement. Any test devised to measure the bonding strength should be simple, rapid, and require only easily operated and rugged apparatus. It is safe to assume that the test for bonding strength and that for permeability, to be referred to later, have thus far received more attention and have had more labour bestowed upon them than any other laboratory investigation methods.

It is not the writer's intention at the present to discuss the nature of the bond. Its presence is acknowledged, and that it plays a vital rôle in strengthening the sand and holding it together in the mould is admitted, as well as assisting it to resist the different forces which tend to disrupt it before, and even during the process of filling the mould.

There still appears to be some difference of opinion as to what forces are operative in disrupting the sand, that is, whether they are tensile, compression, or shearing forces, or a combination of these, which one of these the bond test should measure, or whether they are so related to each other that any form of test which measures the strength of the bond may be used.

There are in the United States three types of test which have been recommended for determining the bonding strength of green sands, viz.: —(1) The bar test which has been standardised by the A.F.A.; (2) a compression test, and (3) a tensile test. The last two are now under investigation by the sub-committee on tests, and recommendations may, no doubt, be expected in the not-distant future.

Bar Test.

This test involves compacting the green sand in a box mould under specified conditions, then removing the bar from the mould and drawing it over the edge of a plate at a given rate of speed. The weight of the piece breaking off varies directly as the strength of the sand.* The breaking of the bar is due mainly to the operation of forces of tension, and with care it is possible to get average breaks which do not vary by more than 5 per cent. as specified in the recommendations of the sub-committee. The one point to bear in mind is that the size of the piece which breaks off of the bar depends primarily (other things equal) on the strength of the bond.

The test as a whole is satisfactory, and is being quite widely used in different foundries for control work. The apparatus requires more space than that used for the compression or tensile test, and wher the sand is too dry there is considerable shearing in the bar, so that the true strength is

* Procédé d'Etude experimentale des Sables de Fonderie, 4me Congres de Fonderie, Paris, November, 1924.

* The strength is represented by the weight of the piece breaking off. *See* A.F.A. pamphlet on test issued June, 1924.

not obtained. It might be said, however, that when the sand gets to that condition it is too dry to work in the foundry.

Compression Test.

For this purpose, the sand is formed into a core, obtained by ramming it in a cylinder, broken in a suitable machine by compression, the results being expressed in lbs. per sq. in., or some other unit. Several types of apparatus are now being tried out in the United States, and all seem capable of giving good results if properly made. One point to be considered is the ratio of diameter to height of sand core tested, for cores of the same sand in which the ratio of these two dimensions vary do not always give the same compression strength per square inch.

A cylinder, 2 in. high and 2 in. dia., yields a higher unit strength than one which is 1¾ in. high and 1½ in. dia., the compaction being the same. From the view-point of mechanics of materials, the latter may be more correctly proportioned, but from the standpoint of practicability the former is easier to make, because it can be moulded in the rammer used for the permeability test, but even after a satisfactory compression test has been made there remains some question as to whether it is an appropriate one for measuring the bonding strength of the sand. There seems no doubt that the chief factor which helps the sand to resist a compressive force is the bond surrounding the grains of sand, and hence it is assumed by some at least foundrymen are really measuring the bonding strength.

Tests which have been made on the same sand for compression strength, and with the A.F.A. bar test, have indicated that the curves of the two may run more or less parallel, but that where both show a peak the two peaks are not always in exact agreement. In favour of the compression test is the fact that the apparatus requires little space, and that it can be used on drier sands than the bar test can. Whether it is more delicate than the bar test is a matter of dispute.

Tensile Strength Test.

This has appealed to some, partly because it was thought more truthfully to measure the type of failure occurring in a green sand mould, but the test itself does not thus far seem to have been developed so that it is capable of being used as readily and with as little practice as the compression or bar test. Most of the experiments made for tensile strength have involved shaping the sand into a briquette similar to that used for testing cement. Such a briquette, if made of moulding sand, has but little strength and requires the most careful handling, and has not found much favour. A modification recently described by Wolf and Grubb* consists in ramming the sand in a core inside of a brass cylinder. This cylinder is divided horizontally, the upper and lower halves being carefully fitted, and kept clamped together while the cylinder is being rammed with sand. The lower end is then fastened to a base, the clamps removed, and tension applied to the upper half. The force required to pull the sand cylinder apart is thus measured. This apparatus is ingenious, and is claimed to be delicate, but it is not yet foolproof, and in untrained hands might give results of doubtful value.

Comparisons.

Whether or not the bar, compression and tensile tests all measure the same stress or not, there seems no doubt that they all determine the strength developed by bonding material in the sand, and that is one factor required, either in studying new sands or in daily foundry control. It is also true that all three of these tests are now in daily use in the United States for control work, being used for testing either single sands or mixtures. The first has been standardised, the others remain to be.

Permeability.

In view of the importance of this property, it is not surprising to find that many have developed apparatus for testing it. That a number of different types of apparatus have been tried in both America and Europe has been well brought out in a Paper by T. C. Adams presented to the American Foundrymen's Association at its Milwaukee convention.*

One important feature stressed in this Paper is that whilst all the different kinds of apparatus determine the ease with which air can be forced through sand, the permeability as determined is rarely expressed in terms of some common unit, so that the figures obtained with one apparatus cannot be checked with those of another.

Adams points out that the permeability apparatus all fall in one of two main groups, as follows:—(1) Those which determine with the aid of a permeability formula the permeability of the sand in some definite units (usually centimetre-gramme-minute units), and (2) those which give the permeability in some very arbitrary unit which depends on the construction of the apparatus.

All results from any apparatus of group (1) are comparable. Those obtained by apparatus of group (2) are only comparable when each apparatus made after a given design is strictly standardised, otherwise the results may not be compared except with other results obtained upon the one individual apparatus.

The Sub-Committee on Tests of the American Foundrymen's Association has spent considerable time on the problem of permeability, and not only were a number of experiments made to clear up doubtful points, but several pieces of experimental apparatus were constructed. Among the factors influencing permeability, which must be taken into consideration in devising a test, are grain size; amount and nature of bond; quantity of moisture in the sand; degree of compaction; height of sand column through which the air is passing, and pressure.

Variation in these factors brings about variation in permeability. The rate of flow of air through a sand is proportional to the pressure causing this flow. It is also proportional to the area of the cylinder, and inversely proportional to its length. This may serve to explain why the Test Committee recommended that the sand be rammed in a core of uniform diameter, height and compaction.

With such a standard core of sand the pressure required to pass the air through can be determined and the time required for a given volume of air to permeate the sand noted. Results which are comparable with those obtained on other apparatus where pressure are thus given, and time can be measured, provided the sand core is prepared in the same manner.

The original apparatus recommended by the committee was essentially that used at the Bureau of Standards. This, while accurate, was not sufficiently rugged, compact, or rapid for foundry use, and so the committee, after trying out several different types, finally evolved the small portable one which it has been recommended and described in the special pamphlet already referred to. It is constructed entirely of brass, with the exception of the two short legs of the manometer tube. It is also accurate when used as a standard apparatus, and the special orifices for rapid work add greatly to its utility. Although this apparatus was recommended not over eight months ago, there are now between fifty and sixty of them in use for foundry control work in the United States.

There may be other types of permeability apparatus devised, either in America or Europe, but the writer wishes to urge that they be constructed and manipulated so that they give comparable results. Some of those described in European magazines can be easily adjusted to give the same results as the A.F.A. model.

(To be continued.)

* American Foundrymen's Association, Preprint No. 430.

* In press.

MR. W. R. BARBER, the manager of the Woolsthorpe Mines (Grantham, Lincs.), of the Stanton Ironworks Company, Limited, died recently at the age of 58.

MR. T. M'ILMOIL, of the Lindens, Bearsden, and a director and secretary of Alexander Stephen & Sons, Limited, shipbuilders and engineers, Linthouse, Glasgow, died on the 25th ult.

MR. J. HOLDEN, who died recently, was a well-known locomotive engineer, having resigned the position of locomotive superintendent of the Great Eastern Railway at the end of 1907.

Malleable Iron.*

By F. H. HURREN, A.I.C., M.I.Brit.F.

The malleable iron industry is one of the largest and most important branches of the foundry trade, but our knowledge has not progressed to anything like the extent one might have expected. The production of malleable iron castings as an industry commenced towards the latter end of the eighteenth century, yet present-time founders are still struggling with many of the same difficulties against which many of their forefathers had to contend. What is the reason? In part it may be due to the laborious nature of research and the very many variable factors which have to be considered. Malleable iron is full of original sin and troubles which, overcome in one direction, crop up in another. The malleable trade has suffered from an excess of secrecy and suspicion. Much of the research has been carried out by private firms at their own expense, and the knowledge so gained has not been published.

The output of malleable castings in Great Britain is quite considerable, the bulk of it being the white-heart variety, but it has the disadvantage of being divided amongst a large number of foundries, the individual output of each being relatively low. The small foundries cannot afford the expense of private research, are not sufficiently well organised to co-operate, and there is a dearth of easily available literature on the subject.

Research on malleable iron takes time. Investigations into casting and annealing cannot be made in a few days nor in a few weeks. The British Cast Iron Research Association will render invaluable service to the foundry trade by a thorough investigation of the difficulties and intricacies inseparable from the production of malleable iron castings. The scope of the necessary research is enormous, and will take years to bring to fruition, but the definite knowledge gained will be well worth the labour involved.

The present use of malleable iron is but a fraction of the potential uses. Malleable occupies a position intermediate between grey iron and steel stampings. It is used where grey iron is not of sufficient strength and ductility, but owing to its vagaries is being superseded by mild-steel castings and stampings. Unless the inherent difficulties in the production of malleable castings are tackled in earnest, future practice will tend more and more to its replacement by stampings and steel castings. If our knowledge was such that we could produce, without fail, a white-heart malleable iron which was soft and ductile, easily machinable, free from hard patches, with a tensile strength of over 20 tons per sq. in. and an elongation approaching 10 per cent., an enormous demand would be set up, and malleable iron would assume a position second to none. Such a state of affairs is not impossible. Tests have been made on white-heart malleable giving results of 23 tons per sq. in. ultimate stress, with 9 per cent. elongation, but unfortunately these results cannot be repeated with certainty.

Basic Differences Between Malleable and Other Castings.

Consider the differences between malleable iron and other casting materials. Malleable iron has a far greater contraction, making it liable to contraction cracks or sears; it has a greater shrinkage in passing from the liquid to the solid state, necessitating special methods of gating and feeding. It is practically unmachinable in the state as cast, and impossible to test in any manner other than a test to destruction. It has to undergo a long heat-treatment, which alters its dimensions and changes its chemical composition and microstructure. Incidentally, this heat-treatment introduces a risk of distortion and cracking. After heat-treatment, its utility can only be gauged by chemical analysis and its machinability. In the present state of knowledge, chemical analysis gives no exact criterion of practical value, as the composition varies according to the thickness of the part from which the sample is taken, and to the depth of drilling. It is not known what should be the proportions of combined and free carbon in different thicknesses of correctly-annealed material. Opinions differ as to the silicon content, also respecting sulphur and manganese. It is known with some degree of certainty that phosphorus has a deleterious effect, and should be kept as low as possible, preferably below 0.1 per cent. Analyses of different makes of malleable castings will reveal silicon contents varying between 0.35 and 1.1 per cent.; sulphur between 0.15 and 0.45 per cent., and manganese from 0.10 to 0.60 per cent. It is absurd to dogmatise, and a very long and careful research is needed to find some definite data on chemical composition. Even then foundrymen would have to compromise. Composition would naturally vary according to thickness of section, and in the same casting it is quite common to find sections varying from 1 in. down to $\frac{1}{8}$ in. thick.

Present Position.

What is the extent of our knowledge of the science of producing malleable iron castings, and how can this knowledge be applied to control production in the foundry? We know that a high silicon content induces brittle castings, with a dark grey fracture similar to common iron. It is known also that a low silicon-content increases the difficulty of annealing; in fact, with a low silicon and high sulphur content annealing is almost impossible. The author has subjected samples of malleable iron containing 0.42 per cent. silicon and 0.45 per cent. sulphur to annealing temperature for 21 days, and at the end of that time only about one-sixteenth of an inch in depth was soft, the remainder of the section being practically unchanged.

Silicon Requirements.

The actual silicon content most desirable is, in the author's opinion, still a matter of conjecture. It is stated by various authorities that the silicon should be lower for heavy sections than for light sections. Complications arise when there are both heavy and light sections in the same casting, and in modern engineering practice this is the rule rather than the exception. All there is to work on is the fact that silicon below 0.4 per cent. appears to retard annealing, and above 0.9 per cent. there is introduced a risk of low strength, loss of ductility, and a state very little better than grey iron. The only possible course is to find the silicon range which best suits the general run of work and endeavour to keep within that range. In the Rover Foundry a silicon content ranging from 0.55 to 0.75 per cent. is called for.

Carbon Control.

Control of silicon is of great utility, but in the author's opinion what is of even more importance is control of carbon content. In the un-annealed casting the carbon should be wholly or mainly in the combined state. The latest theory propounded is that when a certain temperature is reached during the process of annealing, the combined carbon or cementite breaks down, and graphite or free carbon is precipitated. With increase of temperature this precipitation of graphite continues until the proportion of combined carbon falls to about 1.8 per cent. From this point, with continued heating, decarburisation takes place. Now it is obvious that the higher the total carbon content in the hard casting the longer must be the period of heating before the precipitation of graphite ends and decarburisation commences. In other words, to obtain good malleable, an increase in the total carbon content in the hard casting necessitates a longer period of annealing. The author's view, borne out by his personal experience, is that the most ductile, strong and easily machinable castings are associated with a low total-carbon content after annealing, this carbon being distributed as part graphite or temper carbon and part combined as pearlite.

* A Paper read before the Glasgow Conference of the Institute of British Foundrymen.

From experiments which have been carried out over a number of years the conclusion has been reached that the best results are obtained when the total carbon content in the hard casting lies between 2.9 and 3.2 per cent., and it is thought this opinion will be confirmed by others.

Analysis of the usual brands of pig-iron supplied for malleable work invariably shows a preponderance of supplies with a total carbon content above the upper limit of 3.2 per cent. In many instances the author has found pig-irons with a total carbon content of 3.6 per cent., and even higher. The makers of malleable pig would confer a real boon on the founders if they would pay more attention to the composition of the material, and supply an iron with a maximum total carbon content of 3.1 per cent.

Influence of Total Carbon.

In connection with this subject numerous results of experiments could be given, illustrating the effect of total carbon, and the two following have been taken as typical examples. Two samples of hard castings were annealed under practically identical conditions of time and temperature. One contained 3.06 per cent. total carbon in the hard state, and the other 3.38 per cent. total carbon. Representative samples were taken for analysis after annealing. The results are given in Table I.

TABLE I.—*Result of Annealing Two Samples—One with High Total Carbon.*

	No. 1.	No. 2.
Before annealing.	Per cent.	Per cent.
Total carbon	3.06	3.38
After annealing.		
Total carbon	0.58	2.62
Comb. ,, ...	0.14	1.04
Free ,, ...	0.44	1.58
Silicon	0.56	0.61

It will be noticed that No. 1 only contained 0.58 per cent. total carbon, whereas No. 2 contained 2.62 per cent. No. 1 had lost 2.48 per cent. carbon during annealing, against a loss of only 0.76 per cent. carbon in No. 2. No. 1 was soft, easily machinable, and bent through an angle of 90 deg. before showing signs of cracking. No. 2 was soft and easily machinable, but fractured after bending through an angle of about 15 deg. It has been found repeatedly that malleable castings which are soft but non-ductile have a high total-carbon content, and under certain conditions only very slight decarburisation takes place even with an unduly prolonged anneal.

Graphite Precipitation.

Some time ago the Rover works was very much troubled by a certain casting showing a dull surface with black spots in small areas after machining. This occurred on about 25 per cent. of the castings supplied, the castings giving no difficulty in machining, but being very brittle. Analysis revealed a high content of free carbon, and micro-sections showed graphite in a fine state of division. Repeated re-annealings at different temperatures for lengthy periods had but little effect on the carbon content. The author's original opinion was that the trouble was caused by high total carbon in the hard casting, but in the light of later knowledge would assume that a high temperature of annealing was partly responsible. The best results from malleable castings are obtained when the free or temper carbon is in the nodular form. It has been proved recently by Northcott that the rounded or nodular form of temper carbon is produced below 1,000 deg. C., and above this temperature the graphite assumes the flaky structure familiar in grey iron. It is reasonable to conjecture that in the castings just referred to, not only was the total carbon content high, but that some of the castings had been subjected to an annealing temperature exceeding 1,000 deg. C., and graphite had separated in a finely divided state.

Manufacturing Desiderata.

The manufacture of malleable iron castings comprises two distinct operations, the production of the hard castings, and the annealing process. The difficulties met with in the casting stage can be overcome by care and commonsense. Any faults due to the actual manufacture of the casting are usually discovered during machining, and before the article is put into service. Unfortunately, it is during the annealing process that trouble is most likely to develop, and castings which appear perfectly satisfactory fail in service, owing to structural weaknesses induced by incorrect composition. It has been part of the author's duty for many years to investigate causes of failure in service, and he can say, without hesitation, that the majority of failures have been due to irregularities of annealing, and in most instances due to lack of ductility caused by excessive carbon content. The text-book theory of annealing, and the one which is generally accepted, is that the changes occur in two separate phases:—(1) The elimination of carbon from the outer portions of the casting; and (2) a softening of the iron by precipitation of annealing carbon.

Chemistry of Annealing Process.

The universal practice in this country is to pack the castings with a mixture of red and black hematite ores. It is assumed that at high temperatures oxygen is liberated from the ore and reacts with carbide from the outer surface of the casting forming carbon monoxide and free ferrite. The carbon monoxide combines with further oxygen, to form carbon dioxide, which in turn reacts with carbon from the casting, forming carbon monoxide and liberating ferrite. These reactions are continuous, and at a later stage, free or temper carbon is precipitated. This is somewhat at variance with a later theory that, at a certain temperature, there is a partial conversion of cementite into austenite. On further heating the cementite breaks down, and graphite is precipitated. Continued heating results in decarburisation at the expense of the austenite and graphite.

From a number of experiments made, and the experience gained in the production of thousands of tons of malleable castings during the past fifteen years, the author doubts if the earlier and generally accepted theory fully explains the chemical physics of annealing. From tests made, not under laboratory conditions, but in actual works practice, several apparent contradictions arise. These may be worth enumeration.

(1) Castings of the same pattern, of similar original composition, annealed in the same oven under practically identical conditions, have ultimate compositions varying widely in carbon content.

(2) Loss of carbon takes place not only when the packing medium is oxidising, but also with reducing or neutral media.

(3) Loss of carbon does not appear to be directly proportional to mass.

(4) Whilst generally speaking, loss of carbon increases with increased time of annealing, notable exceptions occur.

(5) Intermittent rises and falls in temperature often result in a lower carbon content than a continuously maintained annealing temperature.

(6) Other elements, namely silicon, sulphur, and manganese, have a pronounced effect on the final result.

(7) Better results are obtainable by a lengthy anneal at a comparatively low temperature, than a shorter anneal at high temperature.

Detailed Consideration.

It has been found on frequent occasions in testing samples from the annealing ovens, that two castings of the same pattern taken from adjacent stacks, show considerable variations in carbon content. Drillings have been taken thoroughly to represent the samples, and to be comparable. Instances might be mentioned of total carbon contents of 2.06 and 1.48 per cent. respectively, when it might be reasonably expected that the results would be similar. What is the explanation? Is the ultimate composition influenced by the casting temperature?

If the process of annealing involves a supply of oxygen from the mixed ores used as a packing medium, why is it that loss of carbon occurs when neutral or reducing media are used? Yet such is the case, according to experiments personally conducted. A typical instance may be cited.

Samples cast from the same shank of metal were packed respectively in the standard mixture of hematite ores, in coarse coke, and in well burnt sand. The lids and joints of the test cans were luted with a mixture of sand and clay, to exclude air as much as possible. The total carbon in the hard state was 3.3 per cent. A temperature of 950 deg. C. was maintained, in a gas-fired furnace, for 120 hours, followed by a slow cooling. Thoroughly representative samples were analysed with results shown in Table II. These show that

TABLE II.—*Results obtained from Annealing Similar Samples in Various Media.*

Packing medium.	Mixed ores.	Coke.	Sand.
	Per cent.	Per cent.	Per cent.
Total carbon ..	1.83	2.30	2.40
Comb. ,, ...	0.83	1.00	1.22
Free ,, ...	1.00	1.30	1.18
Silicon	0.64	0.61	0.58

with the mixed ores there was a loss of 1.5 per cent. carbon; with coke a loss of 1.0 per cent., and with sand packing, 0.90 per cent. carbon. If annealing is dependent on the oxygen derived from the ore, how has the elimination of carbon been arrived at when an oxidising atmosphere was not existent? Repetition of this experiment by treatment in one of the works annealing ovens was attended with similar results.

That loss of carbon is not proportional to the mass of the casting has been evidenced on numerous occasions in ordinary works practice, and also in a series of experiments carried out some few years ago. A number of samples were cast from one shank of metal, the samples varying in thickness from ¼ to 1 in. Batches consisting of one sample of each thickness were subjected to various short anneals, the results being very indefinite (Table III). Three examples may be cited, each

TABLE III.—*Total Carbon Content in Annealed Samples Cast from the same Silicon Metal.*

Thickness	¼ in.	½ in.	¾ in.	1 in.
Batch 1	2.77	2.08	2.84	2.18
Batch 2	2.44	2.62	2.66	2.38
Batch 3	2.46	1.99	2.58	2.72

batch being annealed under different conditions of time and temperature. The total carbon content in the original hard castings was 3.18 per cent., and the total carbon after annealing is shown in Table III. These figures need no comment. It would be imagined that according to the general theory of annealing, elimination of carbon would be proportional to the mass.

As might be expected, loss of carbon bears a close relationship to time at annealing temperature, but notable exceptions have been encountered. Several examples might be given, but one will suffice. A certain casting after annealing was soft but not ductile. Analysis showed a total carbon content of 3.16 per cent. of which 2.04 per cent. was free carbon. A further annealing for a total of 300 hours at temperatures between 900 and 950 deg. C., yielded a total carbon content of 3.01 per cent., of which 2.28 per cent. was free carbon. The only explanation suggested is that during the heating-up period of the anneal, the greater portion of the carbon was precipitated as finely divided graphite, and this state does not favour carbon elimination. It appears that success in annealing is only possible when the precipitation of carbon can be retarded until a considerable portion of the carbon has been eliminated. The carbon then precipitated takes the form of temper carbon, instead of as particles of graphite.

In some works, it is the practice, once the annealing furnace is up to heat, to maintain one continuous temperature for the full period of time. Other practice is to have periods when no firing is done, and the temperature in the oven gradually falls. It is then fired up again, raised to the required temperature, and again allowed to cool off gradually, these operations being repeated several times. The non-firing period is usually referred to as "soaking," and too often these soaking periods are made to coincide with the operator's meal times and evenings off. In the Rover foundry, each annealing oven is fitted with pyrometers, the smaller ovens with one thermo-couple, and the larger ovens each with four thermo-couples, all of which are connected to recorders. This system has the advantage of showing a complete day and night record of the anneal. Experience has shown that periods of "soaking" from 960 deg. C. down to 880 or 890 deg. C., are decidedly advantageous. In continuous firing and maintaining one steady temperature, free carbon is evenly distributed in a finely divided state throughout the mass of the casting, whereas intermittent firing and cooling appears to favour the precipitation of temper carbon in the nodular form. It is this latter which provides strength and ductility.

If malleable iron was a simple combination of iron and carbon, the theory of oxidation of carbon and final precipitation of annealing carbon would be capable of definite proof. The process of annealing is complicated by the presence of other elements, namely, silicon, sulphur, phosphorus, and manganese. It has been clearly demonstrated in grey iron that silicon reduces the solubility of carbon, and favours the formation of graphite. This function has been extended to malleable, and it is generally considered that with increased silicon content the loss of carbon decreases. This favours the theory that the primary attack during the annealing process is at the expense of the carbide. With a high-silicon content, carbon is thrown out of solution at a lower temperature, and the resultant material is higher in free carbon than would be the case if the silicon content was low. This is borne out in practice up to a point, but exceptions occur from time to time, and it is these exceptions which the general theory of annealing fails to satisfy. Two examples are given, but these are not isolated cases. Sample castings from the same pattern, but differing slightly in silicon content, were annealed in the same oven under practically similar conditions. After annealing, representative samples were taken for analysis, the results being shown in Table IV. The total carbon in the hard castings

TABLE IV.—*Giving Results of Carbon Content varying with Silicon.*

	A.	B.
	Per cent.	Per cent.
Total carbon	1.10	2.50
Comb. ,, ...	0.42	0.79
Free ,, ...	0.68	1.7
Silicon	0.82	0.65
Sulphur	0.26	0.24

was 3.10 and 3.13 per cent. respectively. Observe that in sample A, although the silicon was higher than in sample B, yet there had been considerable elimination of carbon, whilst in B there had been only slight reduction. Two other samples cast from the same pattern were annealed under identical conditions. The total carbon in the hard castings was 3.05 and 3.21 per cent. respectively, and analysis after annealing is given in Table V.

TABLE V.—*Tends to show that Decrease in Silicon favours Carbon Precipitation.*

	C.	D.
	Per cent.	Per cent.
Total carbon	1.80	3.05
Comb. ,, ...	0.83	1.52
Free carbon	0.97	1.53
Silicon	0.56	0.52
Sulphur	0.24	0.25

Both instances contradict the theory that increase of silicon favours the precipitation of free carbon. What is the explanation?

Personal experience has shown that manganese increases the difficulties of annealing. Many brands of malleable pig contain less than 0.2 per cent., and this small amount may be ignored. When the manganese exceeds 0.45 per cent. there is a tendency towards increased hardness in the finished castings. It would appear that manganese retards the annealing process, and introduces complications which may have a marked effect.

If the process is one of oxidation from the surface and diffusion of carbon outwards from the centre of the mass, one would imagine that increase of temperature would result in increased intensity of reaction. In other words, the higher the temperature attained, within reason, the greater should be the loss of carbon. Yet it is a well-proved fact that better results are obtainable by a long anneal at comparatively low temperatures than by a shorter anneal at higher temperatures. The only explanation which seems feasible is that at the higher temperature the cementite breaks down with precipitation of free carbon, further oxidation ceases, and the material becomes passive. As a typical example of effect of time and temperature, the results given in Table VI

TABLE VI.—*Effect of Time and Temperature on Final Composition.*

	No. 1.	No. 2.	No. 3.
	Per cent.	Per cent.	Per cent.
Total carbon ..	3.34	2.06	1.28
Comb. ,, ...	1.33	0.38	0.88
Free ,, ...	2.01	1.68	0.40
Silicon	0.61	0.59	0.61
Sulphur	0.25	0.25	0.23

are illuminating. All the samples were cast from the same material and pattern, and were annealed in a small gas-fired furnace where the temperature could be closely controlled. No. 1 was annealed for 78 hours at 960 deg. C., No. 2 for 86 hours at 940 deg. C., and No. 3 for 103 hours at 920 deg. C. One curious feature of these results is the effect of rate of cooling on the proportions of combined and free carbon. No. 1 was cooled very slowly to 600 deg. C., No. 2 to 700 deg. C., and No. 3 to 800 deg. C. Below these temperatures cooling was allowed to proceed rapidly. It will be observed that in No. 1 just over 39 per cent. of the total carbon remained in the combined form, against 18 per cent. in No. 2, and 68 per cent. in No. 3. From this it would appear that no harm is likely to result in cooling quickly below 700 deg. C.

Methods of Melting.

There are three methods of melting in malleable foundries, the crucible, the cupola, and the air furnace. In all probability the majority largely favour the cupola. Changes take place in composition during melting in the cupola, there being, as a rule, a loss in silicon and a gain in sulphur content. Numerous tests have been carried out in an endeavour to get an exact idea as to the extent of the changes. The author has proved to his own satisfaction that there is no appreciable difference between the calculated and the actual total carbon content. He has not been able to obtain any definite data as to the loss of silicon during melting. Different tests show different results, and the problem is complicated by the weight of the charges, the proportions of pig and scrap which make up the charge, and the volume and pressure of blast. One authority places the loss of silicon as high as 0.23 per cent., but personal experience has been to show, under normal conditions, an average loss of 0.17 per cent.

The sulphur content certainly increases during cupola melting, but the amount of increase is largely dependent on the quality of coke used, on the coke-iron ratio, and on the fluxing practice. During annealing it has been found on some occasions there is a still further increase of sulphur, whilst at times there is a slight diminution.

Phosphorus and manganese show little or no variation during melting, and are usually present in such small quantity as to have no pronounced effect.

It is the practice in many foundries to use a proportion of annealed scrap on each charge, and this practice has on occasion been strongly condemned. Personal experience has shown that small quantities have no ill effect, but the amount so used should not exceed 5 per cent. of the total charge. In greater quantities it appears to reduce the cooling range of the liquid metal; the iron, although appearing hot and fluid when tapped, rapidly becoming dull and viscous. The statement is sometimes made that the use of soft scrap introduces the danger of free carbon in the castings made from such a mixture, but it is difficult to see that free carbon will persist on melting. It is thought that in molten iron all the carbon must be present in the combined form. It is generally agreed that the presence of free carbon or graphite in the hard casting is deleterious, as this graphite is likely to remain after annealing and cause weakness. Graphite in the hard casting can only be due to a high total carbon content, coupled with a prolonged cooling through the critical range.

Distortion.

One of the most troublesome items connected with the production of malleable castings is distortion during annealing. Speaking generally, distortion in plain castings is due to bad packing in the ovens, to excessive heat, or to sagging of the annealing pans. Distortion in intricate castings may be the result of inequalities of expansion and contraction during heating and cooling owing to variations of thickness in the casting. Whatever may be the cause, distortion introduces the trouble and expense of "setting." This may be a fairly simple operation, or a very difficult one, necessitating the preparation of special dies and tools. Castings can sometimes be "set" in the cold, but heating-up is advisable. Opinions differ as to the wisdom of cold or hot setting, but it must be borne in mind that to obtain a permanent set the material must be stressed beyond its elastic limit. If the setting is performed in the cold there is a great danger of cracking; even if a crack does not develop, the casting has been unduly stressed, and considerably weakened in consequence. In hot setting there is a possibility that during the subsequent cooling the material will partially revert to its pre-annealed state. It is eminently desirable for some definite information to be obtained as to the maximum temperature to which it is possible to reheat malleable castings without risk of destroying the effect of annealing, and also the influence of time and conditions during cooling down again.

Cost of Annealing.

From a purely commercial point of view there are one or two items which demand investigation to enable malleable castings to be produced at a reasonable price and show a fair margin of profit. The two most expensive items are fuel and annealing pans. The old type rectangular furnaces, with fireplaces on either side of the bed, are reasonably cheap to erect, and the cost of upkeep is fairly low. At the same time, they are very extravagant on fuel. They will burn only a good long-flame type of coal, and will not burn slack or small coal. From careful tests made from time to time it is computed that this type of furnace consumes from 36 to 42 cwts. of coal per ton of castings annealed. More modern furnaces have a much lower coal consumption, but suffer from several disadvantages. The firing and manipulation of dampers is usually more complicated, and needs more highly skilled operatives. Firing is more continuous, and entails a night-shift. First cost is generally much higher, and cost of upkeep greater. All things considered, it may be found that the economy in fuel is more than counterbalanced by the increased trouble and expense in other directions. The development of pulverised fuel offers great possibilities in the malleable trade, and there is a wide field for the inventor in improving the efficiency of annealing furnaces.

(*To be continued.*)

MR. R. H. BEST, of Birmingham, died on June 1 at his residence, Hamstead Road, Handsworth, in his 82nd year. Mr. Best, who was associated with the firm of Best & Lloyd, Limited, was born in Birmingham in 1843. At the early age of 14 he entered the business of a manufacturer of brass goods founded by his father, Mr. R. Best, who died in 1863. The firm eventually became a company under its present style. Mr. Best's work in connection with the brass industry was of a far-reaching character. Particularly was this the case with the results of his investigations into the economic conditions of the brass trade in Germany. It will be remembered that Mr. W. J. Davis, then secretary of the Brassworkers' Society, the late Mr. C. Perks, and himself went to Berlin on a tour of inquiry and research.

XUM

A Note on the Practice and Purpose of Perlit Iron.*

By HORACE J. YOUNG, F.I.C., M.I.Brit.F.

For introduction the author wishes to explain those circumstances under which this note has been written.

It is known nowadays to many people that the Perlit process consists of a definite foundry procedure correlated with an equally definite metallurgical control; the moulds are heated to a predetermined temperature to suit the metal with which they are to be filled, while the metal is controlled to a pre-determined composition to suit the average thickness and the mass of the casting it is to occupy.

Obviously, any one portion of the process, as above described and as set out in the patent specifications, can be made to reciprocate with the other and, therefore, it is possible to carry out the method and to attain the desired result in more than one manner. For instance, one foundry may find it convenient to vary the temperature of its moulds and to keep the metal constant; another to use different metals whilst using a similar

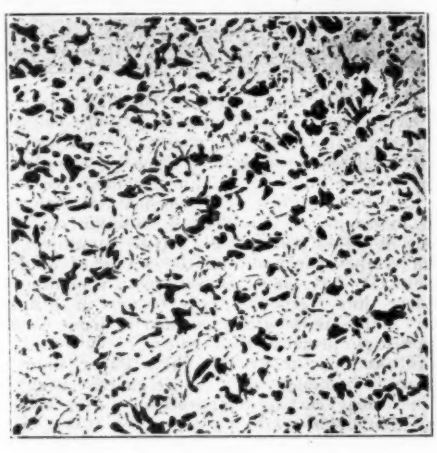


FIG. 1.—PERLIT BAR, CAST 1¼ IN. DIAS. GRAPHITE × 25 DIAS.

mould-temperature throughout; whilst another may have such work as renders it better to vary both factors.

Not long ago the author, reading about this process in the technical Press, found it difficult to evaluate. Much of this difficulty was due undoubtedly to an extravagant and, in some instances, an inappropriate use of the description "pearlitic." A visit to the Continent, in the early part of this year, gave opportunity for personal investigation in various foundries using the process and turning out all classes of work, light, medium or heavy, as the case might be.

The final remark of this preface consists in saying that the process has been in operation in the foundries of the North Eastern Marine Engineering Company for so short a period as to make it impossible for the author to include many of the observations made in those foundries, but he has decided, nevertheless, to admit none made elsewhere and not under his supervision.

Of recent years it has become recognised, from results obtained under service conditions as well as those of many research workers, that grey cast irons containing little silicon possess superior properties to those of higher silicon ranges. Unfortunately, the obstacles in the way of using low-silicon metal often are, for very many castings made under usual foundry conditions, entirely prohibitive. The unreliability of ordinary cast iron lies in the fact that the metal has a varying "grain" according to its section—a complicated casting is "different all over," whilst a plain one has a metal "core." For instance, an ordinary test-bar casting is different in the centre from what it is nearer to the outside. Also is it recognised broadly that grey iron containing the maximum amount possible of combined carbon, without free cementite, is the best form in which any one particular cast iron can be—this form being described as all-pearlitic.

Added to these accepted facts is the knowledge that the graphite should exist in amounts below, say, 2.5 per cent., and that the dimensions, shapes and distribution of the voids, partly occupied by it, should be such as have been found to characterise those irons which have given the best service and exhibited superior physical properties. In other words, these voids should be short, thin, curly or nodular, and confined within the network.

In order to prevent this note from developing into a discussion of matter already proved and accepted by recognised authorities, the author has selected, from the large mass of evidence, only remarks made by British workers which have

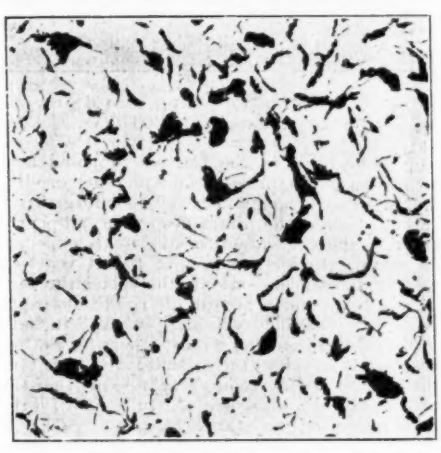


FIG. 2.—PERLIT BAR, CAST 1¼ IN. DIAS. GRAPHITE × 75 DIAS.

appeared in those issues of THE FOUNDRY TRADE JOURNAL of the dates given in parenthesis.

Hilton Mills (July 5, 1923 and July 19, 1923) writes:—"The tensile strength was under 8.0 tons per sq. in. Carbon estimations on the test bar showed: Total carbon, 4.20 per cent.; graphite, 3.40 per cent.; and combined carbon, 0.80 per cent." Further, he writes: "My real contention was, that a high pearlite content was only of use when combined with other structural characteristics, the chief of which is the requisite fineness of the graphitic carbon. A pearlite-graphite structure is undoubtedly the one to aim at, for strength in ordinary sand castings, but the graphite must be the right type."

J. Shaw (Dec. 6, 1923) wrote:—"The essential characteristics of high-grade cast iron may be said to be a fine distribution of the graphite, and a *purely pearlitic ground mass.*"

G. S. Bell and C. H. Adamson (May 8, 1924) state:—"It is fairly certain that the tensile strength varies directly with the closeness of the structures in a particular composition."

F. H. Hurren (May 22, 1924), describing the manufacture of motor-car cylinders, gives the analyses of three different parts *of the same cylinder* and remarks: "The figures are typical of many tests, and, as might be expected, the only difference is in the combined carbon and graphite contents."

J. E. Hurst (16-10-1924) says, in his Paper entitled "Notes on Pearlite Cast Iron" that the fact of Perlit iron being white when cast into a cold mould "at once differentiates between an ordinary cast iron of a pearlite-graphite structure and the product now known as pearlite cast iron."

* A Paper read before the Glasgow Conference of the Institute of British Foundrymen.

Further, he states "It is, generally speaking, well known that an all-pearlitic structure is advisable for the best general resistance to wear." Referring to other properties, he remarks "A most important additional point is that this high tensile strength is secured with a comparatively low Brinell hardness." He goes on to say "Whilst, broadly speaking, foundry metallurgists are well aware of the influence of rate of cooling on the constitution of cast iron, none of us has been aware of the fact that the rate of cooling

FIG. 3.—PEARLITE BAR, CAST 1¼ IN. DIAS. PEARLITE × 400 DIAS.

could be modified in the manner proposed in the pearlitic cast-iron process, and for such modification to be accompanied by such gratifying results." Later, he continues "An all-pearlitic matrix is the best practice. It is his experience with many cylinder problems of recent years that the lower the silicon content, the better the resistance to wear under almost all conditions appertaining in engine cylinder work, including internal-combustion engine or otherwise. From these points of view the pearlite cast-iron structure and the underlying features of the Lanz pearlitic cast iron as defined, fully justify their claims regarding resistance to wear. The distortion of cast iron under heat influences in the engine cylinder is another complex phenomenon . . . . . it is shown here, and has since been confirmed by other investigators, that the lower the silicon content the greater the resistance of the pearlite constituent to decomposition under these

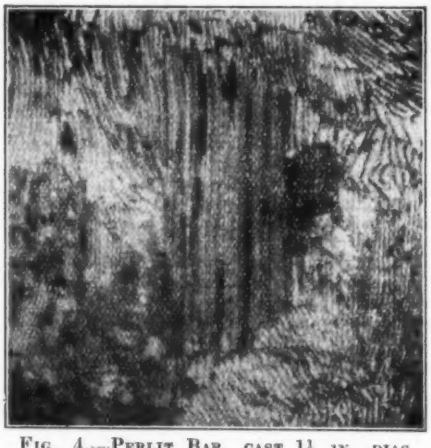


FIG. 4.—PERLIT BAR, CAST 1¼ IN. DIAS. PEARLITE × 1,500 DIAS.

circumstances. It is his opinion that a low silicon and an all-pearlitic cast iron are desirable conditions to obtain the best resistance to distortion arising from the above-mentioned causes." He states "It will be quite clear from the definition of pearlitic cast iron that it is intended to belong to the class of irons which have been described as border-line compositions, and we may expect that this being the case it would be extremely sensitive to the effect of the rate of cooling . . . . . there is no semblance of annealing in the process."

Prof. C. H. Desch (8-1-1925) said "The best cast iron is likely to consist of a strong steel, containing graphite crystals of such small size and so grouped as to produce the least weakening effect. The toughest steel has the composition of pearlite. . . . . There are many reasons why cast iron of close grain, with minute particles of graphite held in a pearlitic ground-mass, is desirable, apart from its strength and machining

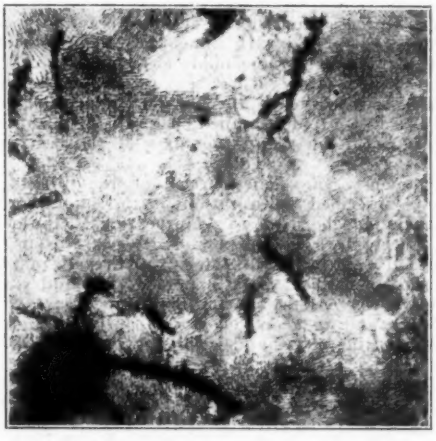


FIG. 5.—PERLIT BRACKET. SECTION ¾ IN. × 400 DIAS.

qualities. Chemical attack, such as the destruction of acid tanks by sulphuric acid, is associated with an open grain . . . . . he has met with striking instances of this action. Similar considerations apply to irons which are to be subjected to high temperatures and to the action of oxidising gases. It has been shown by Carpenter and others that 'growth' only occurs in graphitic irons and is particularly marked in irons containing a high proportion of silicon."

A. Campion (22-1-1925) in a Paper upon the factors influencing the strength of cast iron said "The ideal casting-temperature would be such that the mould could be completely filled, whilst all constituents of the iron are completely in solution, and that they should begin to separate immediately thereafter." He describes suitable cooling conditions as resulting in "normal crystallisation prior to the saturation point of the carbide being reached. Objectionable graphite

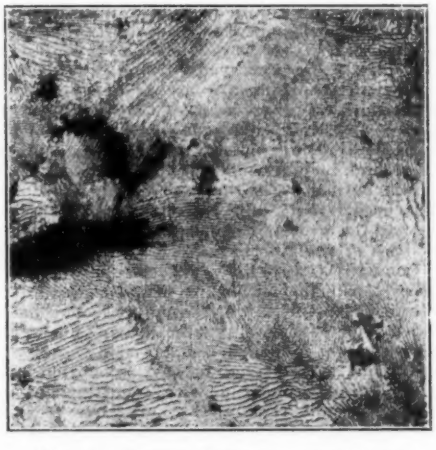


FIG. 6.—PERLIT BRACKET, CAST 1¼ IN. DIAS. PEARLITE × 400 DIAS.

growth is thus prevented, and a mechanically sound structure is obtained."

Prof. T. Turner (29-1-1925) commenting upon the Lanz process said "He was interested to hear the figure of 4 per cent. as the total of silicon and carbon. He was reminded of something that happened forty years ago when he made experiments on silicon in cast iron, and when the bar which gave the best result in a series contained

about 2.2 per cent. carbon and 1.8 per cent. silicon." Further, he stated "The importance was demonstrated of fine-grained graphite . . . . . in other words, it was desirable to produce it in a small flake and almost granular condition." "He was pleased," he said, "to feel that they could, by the application of knowledge now within their reach, ensure material of a high quality and of a uniform character, material which could be

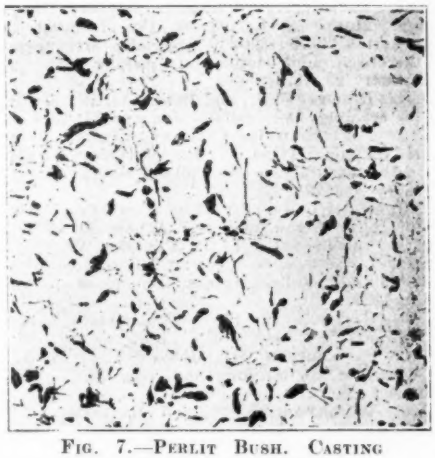


FIG. 7.—PERLIT BUSH. CASTING THICKNESS, 1¼ IN. GRAPHITE × 25 DIAS.

depended upon to resist shock, to give good wear, to give smooth running surfaces, and which would not creep or grow unduly when it was exposed to high temperature."

A. Logan (19-2-1925) said "Slight changes of ultimate composition will produce drastic changes in structural composition. The retention of a little over 0.2 per cent. more carbon in the combined state, for instance, would be sufficient to take up the whole of the free ferrite, and the matrix would then be completely pearlitic." He calculated that 0.50 per cent. of combined carbon forms 59.52 per cent. of pearlite by weight or 54.60 per cent. by volume, and continued "It follows that the strongest irons are those which contain a minimum amount of graphite in the most finely divided form and preferably 'grouped,' and having in addition, a completely pearlitic matrix with only a small amount of phosphide eutectic present."

FIG. 8.—PERLIT BUSH. CASTING THICKNESS 1¼ IN. × 400 DIAS.

Having given the above references, the author thinks it unnecessary further to labour the point involved therein.

Perlit iron possesses some unique properties, one of which is proved by the simplest practical test, namely, that one of trying to break it with a hammer. Recently the author cast a small bracket of Perlit iron, its dimensions being about 9 in. long, 6 in. wide and varying in section from three-quarters to an inch and a quarter. The casting was a poor one and a labourer predicted that he could break it with a tap of his hammer. Ultimately, two men struck it forty times with 20-lb. sledges and the casting remains unbroken. The structure of the metal in the ¾-in. section and in the 1¼-in. section is shown in Figs. 5 and 6 respectively. The magnification in each case is 400 diameters and clearly indicates the fineness of the lamallæ, the all-pearlitic matrix and the fine graphite spaces with some nodular ones.

All properly-made Perlit iron exhibits this remarkable resistance to impact, and the foundry workers are astonished by it. A practical test of this nature is more convincing, perhaps, to the engineer and the foundryman than abstruse results depending frequently upon particular conditions. It would appear to be irrefutable proof that a new and better cast iron has been discovered. When one attempts to visualise the reasons underlying the behaviour of the iron when subjected to this particular test, it becomes evident that the metal will be superior in other directions also. For instance, the size, shape and distribution of the voids, partly filled with graphite, will be superior to those in ordinary cast iron; the matrix will be at its best in all sections, and the grain-size will be more uniform and favourable. That these predictions are true in fact appears to be evident from the microstructure of the Perlit metal. Figs. 1 and 2 show the graphite in a bar cast 1¼ in. dia., whilst the pearlite in the same bar is so fine that much of

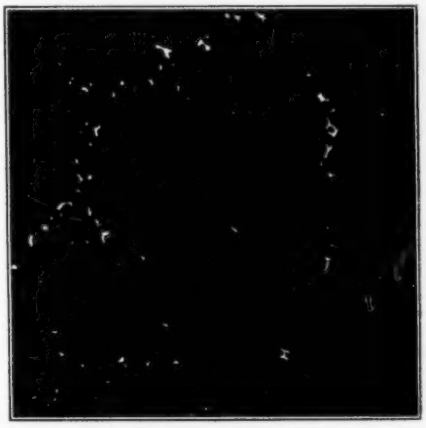


FIG. 9.—PERLIT IRON. PHOSPHIDE NETWORK × 25 DIAS.

it is unresolved by a magnification of 400 diameters, as seen in Fig. 3, whilst at the high power of 1,500 diameters the lamellæ exhibit a beautifully fine texture, as seen in Fig. 4. Similar results are to be observed in Figs. 7 and 8, which represent a bush, 24 in. long, 14½ in. outside diameter, and 1¼ in. thick. In all cases the Brinell hardness has been low, between 175 and 185 being the rule. The network is good, as shown in Fig. 9.

Of course, the photographs given in this note represent the initial results of our work in its very early stages, and it is to be expected, therefore, that much better results will be obtainable as control and experience are attained. Outstanding is the fact that, by this process, can be produced castings, of the thinnest sections if necessary, of low-silicon iron, which will be pearlitic throughout and have graphite voids and pearlitic matrix of superior types to those found in ordinary cast iron, namely, the higher silicon metal suitable for cold-mould practice.

By reason of their being little or no chilling effect upon the metal when it meets the hot mould surfaces, there will be no chilled shell formed, and, moreover, it is not unreasonable to suggest that there is a "hesitation" during which everything has a chance to "level up." This conception enables one to appreciate that much may happen to explain the absence of core and the presence of an all-pearlitic structure throughout an intricate casting made in this manner. Either hot or cold sand is a very poor conductor of heat, and, even though the above-mentioned "hesitation" may exist at or about the freezing point, it does not follow that the metal will pass through

its pearlitic range so slowly as it would do in a cold mould (using a higher silicon metal).

Also it has to be remembered that the voids, partly filled by graphite, may be gaseous. Indeed, their shape and size may be determined by gas influence in the first place. Therefore, the superior voids found in Perlit iron, as compared with those in grey iron cast in cold moulds, may be due to the hot mould not causing the precipitation of these gases at the same period or to the same degree.

The author makes no presumption of understanding the mechanism of the Perlit process. He feels that it is likely to throw light upon many points which have been puzzling foundry metallurgists in connection with grey iron metallurgy; in any case it opens out a new field of research and of manufacture about which, at the moment, there is little data to work upon; all that is known is that the iron is different from and better than ordinary cast iron of higher silicon content, and that it conforms with the opinions of scientific observers as to what good cast iron should be were it possible, as it now is in this process, to make it more uniformly alike throughout any one casting.

The author wishes to express his sincere thanks to Mr. Summers Hunter and to the North-Eastern Marine Engineering Company for allowing this note, describing his impressions and experiences in connection with the starting-up of the Perlit process in their foundries to be presented to this meeting.

Trade Talk.

CASWELL & SHEARING, LIMITED, 812, Salisbury House, London Wall, E.C.2, have removed to 6, Broad Street Place, London, E.C.2.

COCKER BROTHERS, LIMITED, A. and B. Harris, Higgs Motors, George Mann & Company, Limited, and W. Fearnehough, Limited, have joined the Federation of British Industries.

THE WORKINGTON BRIDGE AND BOILER COMPANY have received an order from the Stanton Ironworks Company, Limited, for extensive alterations and downcomers to the Nos. 2 and 3 blast furnaces at their Holwell works.

ONE OF THE BLAST FURNACES of the Millom and Askam Hematite Iron Company, Limited, was put out of blast on June 5, and the only other one which was blowing at the same works was damped down shortly afterwards.

THE SIEMENS AND ENGLISH ELECTRIC LAMP COMPANY, LIMITED, 38-39, Upper Thames Street, London, E.C.4, have the order from the London County Council for the whole of their requirements in electric incandescent lamps for a period of twelve months. Another order is from the L.M.S. Railway for a large quantity of vacuum lamps for train lighting.

THE PERSEVERANCE FOUNDRY COMPANY, Gomersal, near Leeds, advise us that they have removed their foundry address to New North Road, Heckmondwike, where they have greater facilities for dealing with their business, which has expanded beyond the capacity of the premises previously occupied at Gomersal. The head office continues as hitherto at the Grange Works, Batley.

THE TASK OF removing and repairing six large lock gates weighing 160 tons each has just been completed by the London Midland and Scottish Railway at Grangemouth Docks. These gates, which control the entrance to the docks from the sea, measure 47 ft. 6 in. by 35 ft., and in thickness vary from 2 ft. to 6 ft. 6 in. They were removed, repaired and replaced without interfering with the ordinary working of the docks.

THE SHIPBUILDING OUTPUT on the Clyde during the past month was the lowest of the year. Altogether 16 vesse'ls were put into the water, the total measurement of which was only 22,022 tons. This brings the total for the past five months up to 92 vessels of 259,506 tons, compared with 97 vessels of 184,296 tons last year, 45 of 137,145 tons in 1923, and 105 vessels of 293,997 tons in the first five months of 1913, when the highest figures were recorded.

MR. FRANK THOMAS, who was formerly a partner in J. B. Corrie & Company, has commenced business on his own behalf as an engineer's agent at 4, Ravenslea Road, London, S.W.12. He is representing Tubes, Limited, of Birmingham, for the home counties, excluding London, and is also interested in the supply of works' locomotives, fireless locomotives, pit fans, cages and winches, coke-ramming machines, turntable and traversers, steam engines, air compressors, bucket elevators, iron castings, workshop stoves, and stampings.

Patent Specifications.

Particulars of complete specifications accepted, furnished by Mr. Eric Potter, Patent Agent, of Lonsdale Chambers, 27, Chancery Lane, London, W.C.2. Printed copies of the specifications in the following list are now on sale.

232,656. HADFIELD, SIR R. A. Alloys. December 27, 1923.

232,663. DABRITZ, G. Furnaces. January 18, 1924.

232,679. MOND, A. L., METAL AND THERMIT CORPORATION. Refractory materials, articles made therefrom, and method of making the same. January 23, 1924.

232,687. RHODES, C. J., and BERRY, G. W. Machines for seaming sheet metal. January 24, 1924.

232,712. MELLINGRIFFITH COMPANY, LIMITED, THOMAS, H. S., and DAVIES, W. R. Machinery employed in the manufacture of tinplates, sheets, etc. February 2, 1924.

221,210. SCOVILL MANUFACTURING COMPANY. Machines for rolling screw threads. August 30, 1923.

223,029. TAPLIN, JUN., T. J., PERKINA, W. G., and METAL PRODUCTION, LIMITED. Treatment of ores containing oxidised copper compounds. January 29, 1924.

233,059. GAINES, F. S. Sheet-metal pipes or culverts. February 5, 1924.

233,111. FAIRBROTHER, H., MOONEY, LIMITED, A. G. Apparatus for forming shoe shanks. April 7, 1924.

233,110. WRIGHTSON, S. S., and MATTHEWS, C. R. Railway and tramway joints or switches. April 7, 1924.

233,164. WILDER, C. E. Moulds for use in centrifugally casting metal. June 2, 1924.

233,170. FISCHER, P. Clamping contrivance for use in connection with machines for cutting off pipes. June 11, 1924.

232,181. AMSLER, A. Machines for testing materials under repeated stresses. April 23, 1924.

219,293. DEUTCH LUXEMBURGISCHE BERGWERKS UND HUTTEN AKT GES. Hard alloy. July 16, 1923

233,194. PETTERSON, K. G. V. Apparatus for producing moulding cores. July 3, 1924.

231,816. L'AIR LIQUIDE SOC. ANON. POUR L'ETUDE ET EXPLOITATION DES PROCEDES, G. CLAUDE. Autogenous welding of aluminium, magnesium, and their alloys. April 1, 1924.

233,205. HAAS, A. L. Apparatus for testing hardness by impact. July 31, 1924

233,235. DAVIES, W. H. E. R., and RAINE, W. Apparatus for supporting portable tools, such as a riveting machine, drilling machine holder up. October 10, 1924.

230,016. HOLLEY, E. Method of making cores for foundry moulds. February 25, 1924.

233,424. RHODES, C. J., and BERRY, G. W. Flanging and seaming of sheet metal. February 7, 1924.

233,464. RUDOLPH, G. Manufacture of flexible metallic tubing. February 22. 1924.

233,520. BANGER, H. Moulding machines. May 16, 1924.

217,568. HOGANAS BILLESHOLMES. AKTIE BOLANG. Production of aluminium oxide. June 15, 1923.

233,568. SMITH, A. R. Method of and apparatus for hot forging. July 25, 1924.

233,851. STONE, W. L. Centrifugal pipe spinning machines. April 10, 1924.

233,914. PIEL, C., and ADEY, C. Apparatus for casting work pieces of copper alloys having a high melting point. June 23, 1924.

218,303. VERNEY, J. L. L. Means for automatically controlling the temperature of furnaces. June 28, 1923.

233,983. DAVIES, E. W. Apparatus for the automatic manipulation of metal ingots, etc., at rolling mills. October 31, 1924.

226,538. GELSENKIRCHENER BERGWERKS AKT. GES. Casting hollow metal bodies. December 17, 1923

W. T. HENLEY'S TELEGRAPH WORKS COMPANY, LIMITED, announce that in future their address will be described as Holborn Viaduct, E.C.1, leaving out the number 11, which previously has been included.

STRIKES IN BELGIUM.—The Syndicate of iron and steel workers in the Charleroi district called their men out on strike on May 31 last. The men had accepted a 5 per cent. reduction in wages, but the employers are pressing for a further reduction of 5 per cent., to which the men will not agree. It is feared that the strike will extend to the workers in the whole country. According to a later report, the date on which the strike is to begin has been postponed till June 15.

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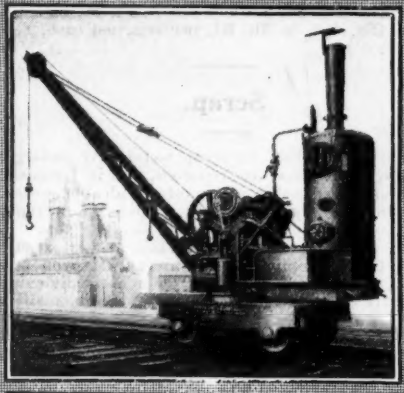

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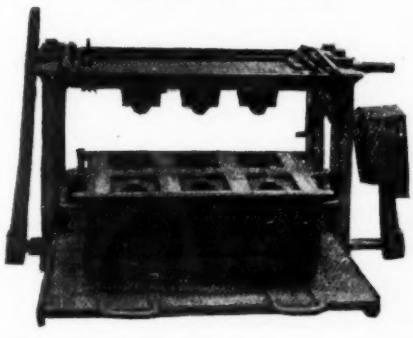

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IRON AND STEEL MARKETS.

Pig-iron.

MIDDLESBROUGH.—Resuming business after the holiday interruption, the position of the Cleveland iron market disclosed little improvement on its previous inactive conditions, with home consumers still reserved in their attitude as regards fresh commitments, and buying, as a rule, being strictly confined to only the most pressing requirements. As a matter of fact, the feeling generally prevailing is that the downward move in prices is not yet ended, notwithstanding that production is only limited, and any recovery in demand would quickly react upon values. The export position is as disappointing as ever, the shipments of pig-iron from Middlesbrough and Skinningrove during May having amounted to 29,219 tons, as compared with 30,635 tons in April and 35,915 tons in March. With the present stagnant conditions, prices continue weak, No. 1 being quoted at 78s. 6d. per ton, No. 3 G.M.B. 74s., No. 4 foundry 73s., and No. 4 forge 72s. per ton.

Demand for hematite on home account remains poor, and although there is a somewhat better inquiry from abroad, especially for silicious brands, the aggregate volume of business is not equal even to the present restricted output. Prices are easy, East Coast mixed numbers being quoted at 79s. 6d. per ton and No. 1 at 80s. per ton. On the North-West Coast, Bessemer mixed numbers are nominally quoted at 87s. 6d. c.i.f. Welsh ports, 91s. per ton delivered at Glasgow, 96s. per ton delivered at Sheffield, and 98s. 6d. per ton delivered at Birmingham.

LANCASHIRE.—The inactivity now prevailing in the local foundry industry is reflected in the conditions of the Manchester iron market, in which keen competition for even the smallest orders is having a weakening effect upon prices. For example, Northampton foundry iron has been openly reported at 67s. 6d. per ton on trucks at the furnaces, equal to about 80s. delivered in Manchester, a movement which can scarcely fail to affect the prices for Derbyshire. Theoretically, Derbyshire was quoted here at 83s. 6d. delivered up to the beginning of the holiday, but there were rumours of 81s. 6d. and even 81s. before then. With Northampton at 67s. 6d., sellers of Derbyshire can scarcely expect to secure more than 72s. 6d. at the furnaces, or equal to 80s. in Manchester.

THE MIDLANDS.—In common with the conditions existing in other districts, markets in this area are becoming gradually weaker; buying is on a very restricted scale indeed, and only in isolated cases can be found forward buying taking place. With a falling market, it would be surprising if it were otherwise. Ruling prices are as follow:—Derbyshire No. 3 foundry, 72s. 6d. to 74s.; Staffordshire No. 3 foundry, 72s. 6d.; Northants No. 3 foundry, 67s. to 68s.

SCOTLAND.—Only a limited demand is in evidence for Scotch foundry pig, which is now only being bought in 20/50 ton lots, as a rule. The light castings producers, being fairly busy, are able to go in for larger parcels, but Cleveland is the quality purchased. Prices continue to sag, and No. 3 Scotch is now quoted at 84s. at the furnaces, whilst No. 3 Cleveland is offered at 78s. per ton, f.o.t. Grangemouth. No. 3 foundry Continental is being pressed for sale.

Finished Iron.

Business in most departments of manufactured material remains more or less quiet, mostly the latter, with, at present, few signs of more active conditions in the near future. Makers of marked bars, hitherto fairly well employed, have now reduced the price to £14 10s. per ton f.o.t., while Staffordshire crown iron is down to £12 7s. 6d. per ton. It is difficult to see how the position affecting the cheaper iron can appreciate to any extent while acute foreign competition prevails. At the present time there is a difference of nearly £4 10s. a ton between the Belgian and Staffordshire price for fencing and nut and bolt iron, and one cannot see this gulf being bridged yet. Continental No. 3 iron is offered here at £7 per ton delivered against the local quotations of £11 7s. 6d. per ton.

Steel.

In the Sheffield market for steel at the moment there is a minimum of business in basic billets, but transactions in acid qualities make up a fair total. There is a little more doing in crucible steel. Wire, cold-rolled strip and steel sheet departments are not fully employed, but most of the railway material departments are well occupied. Engineering tools for abroad make a satisfactory feature, a number of good orders having come to hand recently. Prices of tinplates are lower all round owing to the fact that makers are competing keenly for July-August shipments; 19s. 9d. has been taken in quite a number of cases, and even less in one or two instances. For the standard sizes current quotations rule as follow:—Coke tinplates: IC, 14 x 20, 112 sheets, 108 lbs., 19s. 10½d. to 20s. 3d. per box; IC, 28 x 20, 56 sheets, 108 lbs, 20s. 4½d. to 20s. 9d. per box, net cash, f.o.b. Wales.

Scrap.

The various markets for scrap metal have undergone no improvement since last reported, and in Lancashire cast material especially is almost unsaleable, even at the extremely low prices current, founders now expecting to buy best qualities under 80s. per ton. In Scotland the iron foundries are still rather short of work, with the result that machinery cast-iron scrap is weak, and even at 83s. 6d. per ton it is difficult to find buyers. Ordinary cast-iron scrap is in a similar position, and is offered at 75s. to 77s. 6d. per ton. Cast-iron scrap in furnace sizes can be obtained at 72s. 6d. to 73s. 6d. per ton, and for cast-iron railway chairs parcels have been disposed of at 80s. to 81s. 3d. per ton. The above prices are all per ton delivered f.o.t. consumers' works.

Metals.

Copper.—Although the turnover in standard copper has of late been on a comparatively restricted scale, values have been steadily maintained round about the £60 mark, with occasional fluctuations of fractional extent, but without special significance from a market point of view. The prevailing impression would appear to be that the metal is now as cheap as it is likely to be for some time to come, and consequently consumers feel confidence in buying, which necessarily has a steadying effect upon markets all round. Current quotations:—*Cash*: Thursday, £59 17s. 6d.; Friday, £59 17s. 6d.; Monday, £59 15s.; Tuesday, £59 5s.; Wednesday, £59 7s. 6d.

Three Months: Thursday, £60 17s. 6d.; Friday, £60 17s. 6d.; Monday, £60 12s. 6d.; Tuesday, £60 5s.; Wednesday, £60 7s. 6d.

Tin.—Movements in the tin market of late have disclosed an irregular tendency, but with values on the whole rather more inclined to lower levels. Sentiment in the market has evidently been influenced by reports from Malaya that the May shipments will turn out considerably more than had been originally anticipated, estimates of the total varying up to well over 7,000 tons. Efforts to depress the market were thus renewed more vigorously, and values latterly have reacted sharply in the latter dealings. Current quotations:—*Cash*: Thursday, £251 5s.; Friday, £255 5s.; Monday, £254 5s.; Tuesday, £253 7s. 6d.; Wednesday, £253 12s. 6d.

Three Months: Thursday, £252 5s.; Friday, £256; Monday, £255 5s.; Tuesday, £254 10s.; Wednesday, £254 12s. 6d.

Spelter.—With buying on a more restricted scale, the market for this metal is passing through a dull period, but holders have exercised no pressure to sell, and prices have on the whole remained comparatively steady. Only small quantities have been offered by Belgian producers so far, but next month supplies are expected to be on a heavier scale. Current quotations:—*Ordinary*: Thursday, £34; Friday, £34 5s.; Monday, £34 5s.; Tuesday, £33 18s. 9d.; Wednesday, £34 2s. 6d.

Lead.—The market for soft foreign pig has been firmer, and sentiment generally is improving. Arrivals are heavier, and there is some metal going into warehouse, but it is quite possible that later on in the year further stringency in regard to supplies will make itself felt. Sentiment in regard to the metal is decidedly better, and firmer markets are clearly foreshadowed by the course of events during the last week or so. Current quotations:—*Soft foreign (prompt)*: Thursday, £33 15s.; Friday, £34; Monday, £34 5s.; Tuesday, £33 17s. 6d.; Wednesday, £33 13s. 9d.

MR. H. C. DEWS, Hon. Secretary of the West Yorkshire Metallurgical Society, has been appointed metallurgist to Dewrance & Company, 165, Great Dover Street, London, S.E.1.

THE IMPORTS OF foreign iron ore at the Senhouse dock at Maryport during May amounted to 11,300 tons, against 4,000 tons for the previous month, and 15,780 tons at the corresponding period of last year.